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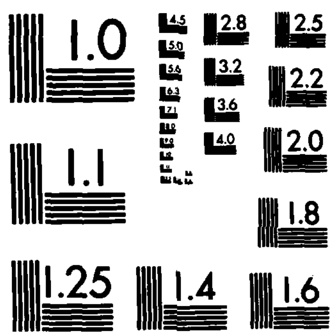

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A SYSTEM DYNAMICS POLICY ANALYSIS
MODEL OF THE AIR FORCE ENGINE
MANAGEMENT SYSTEM

Gordon K. LeMai-.e, Captain, USAF

LSSR 92-82

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The Air Force contains several complex management systems. These systems are, for the most part, examples of goal-oriented, feedback control systems. They often display counter-intuitive behavior in their operations. One of the best ways to study these systems is by using computer simulation techniques. Forrester has developed a system dynamics simulation technology, DYNAMO, which can be used to study such complex systems. The Air Force engine management system is one of these systems. Additionally, it is an example of a multi-item, multi-echelon production and inventory system. Forrester's work with these systems indicated that they are unstable and this instability is due to the structure of the system. This thesis modified an existing DYNAMO simulation model to study the operation of the engine management system. Personal experience, interviews with system managers, and a literature review indicated that this was an acceptable choice. The results of the model's operation were reported. The model is a reasonable approximation of the engine management system. Recommendations for model expansion and improvement are presented.

LSSR 92-82

A SYSTEM DYNAMICS POLICY ANALYSIS MODEL OF THE AIR FORCE ENGINE MANAGEMENT SYSTEM

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

Gordon K. LeMaire, BS
Captain, USAF

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This thesis, written by

Captain Gordon K. LeMaire

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

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CHAPTER 1

INTRODUCTION

Overview

In the last three decades, the U.S. Air Force has spent nearly nine billion dollars on its engine inventory. This inventory, if replaced today, would cost approximately fourteen billion dollars (based on 1979 dollars). The value of this inventory alone, if the Air Force was a for-profit organization, would place it fourth on Fortune magazine's list of the top 500 companies (15).

During this same period, the United States and its NATO allies have had a numerical and technological advantage over the Warsaw Pact. Today, however, it is acknowledged that the Warsaw Pact nations hold a numerical advantage in land and air forces and any remaining technological lead is considered small (26:40). Given this growing disadvantage, and recognizing that aircraft engines must be available in adequate numbers in order to meet requirements, it is easy to see why such a valuable inventory must be managed closely.

Air Force maintenance is a three tiered system. At base level are two tiers. The first tier, organizational maintenance, deals with the day-to-day activities of the flightline. This function performs maintenance activities such as, tire changes, filter changes, drawing SOAP (Spectrographic Oil Analysis Program) samples, and pre- and post-flight inspections. These types of activities are commonly referred to as on-aircraft or organizational maintenance. The other tier at base level is called intermediate maintenance. This function deals with those actions which require a specialist and are performed most often in a shop rather than directly on an aircraft.

The third tier of Air Force maintenance occurs at Air Logistic Centers (ALCs) or depots. These depots are responsible for time-phase overhauls, major repairs, and modifications to reparable assets. Aircraft, engines, and various types of electronic equipment are examples of these assets.

Engine maintenance can take two forms, scheduled or unscheduled. Scheduled maintenance occurs when a certain operating time limit is reached. Once this time is passed, or as soon afterward as practicable, the engine is removed and shipped to a depot were an overhaul is accomplished. Once the overhaul has been completed the engine's clock is set to zero and it is considered to be "new." Unscheduled maintenance occurs when a discrepancy is noted in an engine. An attempt is made to correct that discrepancy while the engine is installed in the aircraft.

If the nature of the problem precludes repair, the engine is removed and an attempt is made to repair it at base level. If repair is impossible or infeasible, the engine is sent to a depot where the engine is repaired or rebuilt (12; 13).

Engines are "life of type" purchases. The entire stock is bought just prior to or during aircraft purchase. No engines are purchased after the initial buy. A defective engine, therefore, is repaired and an old engine is overhauled (15; 27:p.9-1; 12; 13).

While the initial purchase is important, the greatest impact on operations occurs during system life. An underbuy will result in an unacceptable number of aircraft being "not mission capable supply" (NMCS) for engines. An overbuy will result in enormous amounts of money being channeled into unneeded, expensive excess inventory (15; 27:p.1-1).

Money spent on the procurement and maintenance of an engine inventory cannot be spent on some other facet of operations. Every purchase made has an opportunity cost (the net economic benefit that would have been derived from the next best alternative course of action) associated with it (22:567). For this reason alone, decisions which impact engine management must be studied carefully.

Each engine type is monitored by an item manager and assigned to specific ALCs for depot level maintenance (13). In addition to being viewed as an end item, an engine also is considered a line replaceable unit (LRU) while it is installed (20:393). Because of this, spares are locally authorized to support removal and replacement actions (20:393).

The foregoing description establishes the engine management system as a multi-item, multi-echelon production and inventory system. A multi-echelon inventory system is one which has stocks of items at different warehouses were the warehouses have a supplier-user relationship (10:5). In the engine system, the tiers at the base and depot are the major echelons. The depot acts as a supplier and the base as a user (25:2).

Multi-echelon inventory systems tend to be unstable (11:145; 5:33). Inventory levels will be stable when demand is stable. But they will fluctuate when demand fluctuates, and inventory will vary more than demand. These inventory oscillations will be aggravated by the presence of additional levels, regional warehouses for example, between the source of the inventory and the demand (11:145; 5:33).

Forrester did extensive work with multi-echelon production and inventory systems. He showed that oscillations in inventory levels are a characteristic of the system structure. He further demonstrated that a reduction in pipeline times, the amount of time an inventory is in transit, tends to reduce these oscillations (11:145; 5:33). This research will focus on the effects of changes in pipeline time on the availability of engines at base level.

Problem Statement

Air Force engine management has two goals: The first is the supply of serviceable engines to users at base level during peace time. The second, and most important, is the supply of serviceable engines to units participating in combat operations.

A need exists to study the effects of changes in the repair pipeline, the time required to repair an engine, on the engine management system. This thesis will present a simulation model which serves this purpose.

Justification for Research

Air Force Logistics Command employs many models. Among these are ORLA, Optimum Repair Level Analysis, METRIC, Multi-Echelon Technique for Recoverable Item Control, and MOD-METRIC, a modified version of METRIC. ORLA is a study done by a contractor as part of the system/equipment engineering analysis process. It provides a basis on which to evolve an optimum approach to repair or discard recommendations (20:497). MOD-METRIC is a model which deals with minimizing the total expected level of backorders for a higher indentured assembly, subject to an investment constraint (20:459). Both of these models are based on only one facet of the engine management system. ORLA deals with repair or discard decisions. MOD-METRIC deals with inventory.

This thesis will present a system dynamics model of the engine management system. The model is developed to consider repair processes, ordering and resupply, transportation delays, quality, and the information structure of the system. As developed, the model has four characteristics. They are:

1. The model is active and dynamic. The former characteristic deals with the repair and replacement of assets. The latter is concerned with the time dependent behavior of the system. Since as engines are used over time they become unserviceable and require repair and replacement, this is consistent with the engine system.

2. It is flexible enough to accomodate the complex interactions of a multi-item, multi-echelon system. Again this is consistent with engine management because it is a multi-item, multi-echelon system.

3. It is able to identify the length of time the system is in an unacceptable condition. This is to allow for the study of changes in the system which might adversely affect the systems' operation.

4. The model contains expected system failure times as underlying parameters. Most components have a

distinctive failure interval. By incorporating these into the model more realistic results can be expected (3:170-174).

Clark (1:59-62) has pointed out the need for such a model to aid logistics managers in the analysis of resource system goals. Too often managers tend to be narrow in their view of a system and the manner in which it operates. This "tunnel vision" occurs because managers tend to focus on their own area of concern and do not consider the impact their decisions might have on other areas of the system (25:4).

Any system which relies upon the interaction of all its component parts to function correctly can be called a complex system (17:1; 6:p.1-1). Such complex systems can best be studied by use of computer simulation (21:10-11). Utilizing simulation techniques to study real world systems has several advantages. For one, it is safer than making changes in a system just to see how that system reacts, it might cease to exist! Another advantage of computer simulations is the speed with which results can be obtained. An experiment on a real world system, if planned for six months, will take six months. A computer can simulate such an experiment in a very small fraction of that time. Additionally, it can repeat the simulation several times in order to allow for the gathering of statistical data on the results of the different runs (5:17-18; 21:10-11).

It is difficult to determine the exact effect any one decision will have on a complex system. The main reason for this is that most managers use a mental image of their system which focuses on those processes which impact on their area of responsibility (24:4). This fact makes it extremely difficult to ascertain the impact policy changes will have (1:2). In this era of tight money and an increased emphasis on readiness, methods to assess the impact of policy decisions must be developed.

Employing dynamic models in an attempt to analyze the control and behavior of complex systems is called system dynamics (17:1; 3:2). Roberts (18:4) notes that the behavior of a system is determined by its structure. This structure includes not only the physical, but also the traditional aspects of the system. Considering every aspect of a system is a monumental task and becomes nearly impossible without some underlying structure to guide the research. This structure will be provided by using the system dynamics approach which "provides a beginning for replacing confusion with order [18:4]."

Scope

This research has as its objective the development of a policy analysis model of the Air Force engine management system. In order to achieve this the system dynamics analysis technology developed by Forrester

(5; 6), will be used. While this technology is extremely powerful, it will not produce an ultimate model. The reason for this is that for any given system there are any number of models which can be developed. The choice of a model must be based upon the questions being asked (5:60; 18:38; 21:19). This forces the researcher to focus on a more specific purpose than the simple modelling of the system under study (17:18).

The purpose of this research is to study the effects of changes in pipeline times on the availability of engines at base level. The question now arises as to how the effectiveness of the model will be measured. In todays Air Force, a great deal of emphasis is placed on readiness. But readiness is a rather nebulous subject and while the availability of engines will impact readiness, there can be no real measure of how great the impact will be. A better measure of effectiveness would be the furnishing of a sufficient number of engines at base level to keep the assigned aircraft operational.

A model, as described, will be a representation of the engine management system. It displays system behavior in response to policy changes or other disturbances. The effectiveness of model performance will be based on keeping the assigned unit aircraft operational with respect to engines.

The General Electric J-79 engine will be used as a specific engine for this study. There are several reasons for this selection. The J-79 is in use on the F-4, the Israeli Kfir, and F-104 (23; 24; 4). Since the engine has seen such extensive duty, a model representative of the entire engine system is possible with the J-79. Such a model would require only minor changes to fit other specific engine-aircraft systems.

Research Objectives

The major objective of this research is to develop a system dynamics model which demonstrates the effects of policy changes on the availability of serviceable engines at base level. Subobjectives include:

1. Identification of the major processes of the engine management system;

2. Analysis of the elements of these processes, their structure and relationships, and the attributes of these elements and relationships;

3. Development of a mathematical model which mirrors the engine management process;

4. Development of a computerized model from the mathematical and system dynamics models of the system;

5. To verify the performance of the model and validate that the model represents the system;

6. To evaluate the model as a policy development and analysis tool;

7. To identify areas of concern for policy makers (5:13).

Plan of Presentation

This chapter has established and presented background for the research. It has established the scope of the research and presented objectives and subobjectives for the study. The next chapter will present the methodology used in model development. Chapter three traces the model from initial conceptualization through computerization. The fourth chapter focuses on validation of the model by experimenting with changes in the input function. The final chapter summarizes the research findings and presents recommendations for further study.

CHAPTER 2

METHODOLOGY

Introduction

Chapter one laid the basic groundwork for the development of a dynamic policy analysis model of the Air Force engine management system. Discussed in this chapter is the methodology employed in model development. Causal loop diagrams, flow diagram symbols and system equations for a model will be presented and discussed.

The Systems Science Paradigm

The systems science paradigm will be utilized to guide model development. The main reason for this choice is its ease of conversion to DYNAMO, the simulation language chosen for this project. The paradigm, as described by Schoderbek, Schoderbek, and Kefalas (19:279-306), is divided into three phases; conceptualization, analysis and measurement, and computerization. Each of these phases now will be discussed.

Conceptualization

The systems science paradigm begins with system conceptualization. Included in this conceptualization are those processes considered to be relevant to system behavior. In analyzing these processes, the model builder must search out the goals and major outputs of each process and the requirements for that output. The conceptualization phase focuses on the structure and relationships of each element in the system and the attributes and relationships of these elements. This framework is shown in Figure 2-1 (19:5-22)

INPUT →	PROCESS →	OUTPUT
Resources Requirements	Elements (Structure, Relationships, and Attributes)	Goal Measurement

Fig. 2-1

Analytical Framework of the Conceptualization Phase

The major thrust of the conceptualization phase is to start understanding the interactions of the system, both internal, between elements, and external, between the system and environment, as soon as possible. Because of the complexity of these interactions the analyst must first begin with a general picture of the system and refine the model into higher degrees of resolution (19:297). This model building can and should begin early. As soon as enough is known about the structure and relationships in the system to do so (18; 8:5).

A good place to start building a model is to develop causal-loop diagrams, diagrams based upon the feedback loop characteristics of the system (25:15). In building these diagrams, hypothesized relationships between the elements are specified by considering the elements pairwise. An arrow is used to designate the dependent-independent variable relationship. A "+" or "-" sign indicates the relationship between the two variables. These pairwise relationships are then assembled into a cause and effect diagram of the feedback structure of the system.

An example of a causal diagram depicting engine usage is shown in Figure 2-2. As the flying hour program increases, the flying hours per aircraft will also increase. As the hours per aircraft are increased the demand for engines will go up and cause an increase in unserviceable engines. At the same time, the serviceable engines inventory will decrease. However, increasing the serviceable engines inventory will increase the number of serviceable aircraft. This increase in serviceable aircraft will decrease the number of flying hours per aircraft.

The positive or negative signs at the head of an arrow indicate the relationship between the variable at the tail and the one at the head. If there is a plus sign at the arrowhead a direct relationship exists. An increase or decrease in the variable at the tail will cause a like change in the one at the head. A minus sign indicates the existence of an inverse relationship. An increase or decrease in the variable at the tail will have an opposite effect on the variable at the head.

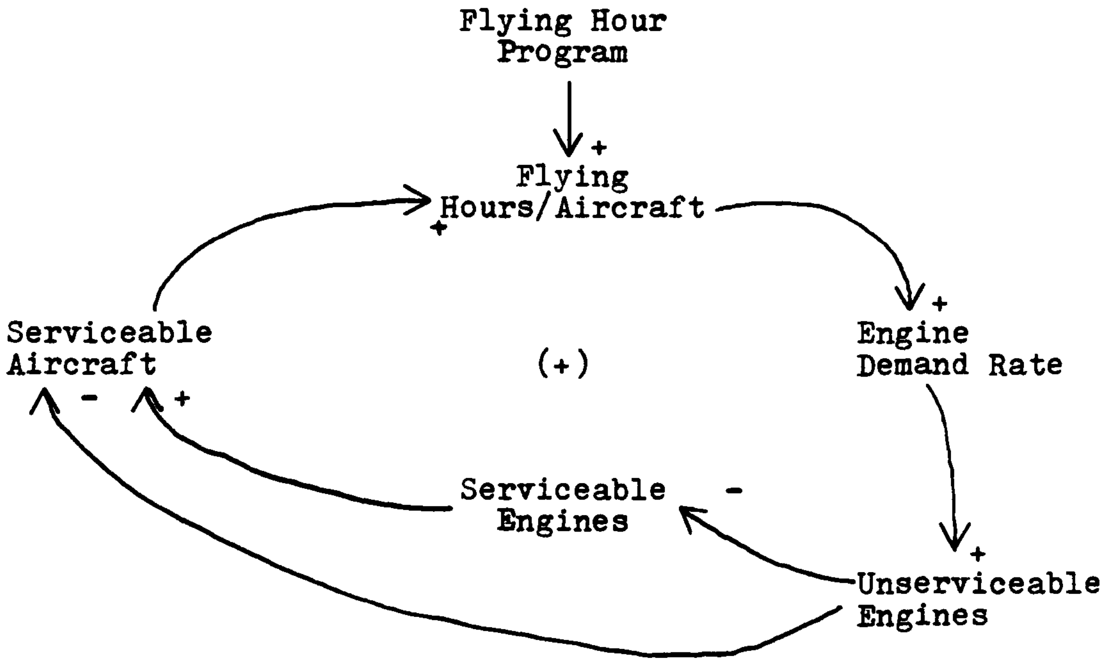


Fig. 2-2

Engine Usage
an Example of a Causal Loop
Diagram

A causal loop diagram can be either positive or negative. A positive feedback loop, as shown in Figure 2-2, is characteristic of growth systems. The positive feedback can lead to uncontrollable growth or decay. If one or more such loops exist in a system, that system potentially is unstable. Conversely, a negative feedback loop is one which opposes change. Any system which contains these loops potentially is stable. The existence of negative or positive feedback loops can be determined by counting the number of minus signs around the loop. If there are an even number of these signs then the loop is positive. An odd number of minus signs indicates a negative feedback loop (17:7-8; 8:15,16).

In constructing causal loop models of a system, further definition of that system is achieved. Once this is completed the next phase, analysis and measurement, can be initiated.

Analysis and Measurement

The second stage of the systems science paradigm involves further analysis of the hypotheses put forth during conceptualization. Two major items come out of the analysis phase. First a flow diagram is developed from the causal loop diagrams. Once the flow diagram is complete a set of mathematical equations which quantify the interactions depicted in the flow diagram are developed. In this sense, system dynamics technology is excellent for this stage of model development. The flow diagram symbols shown in Figure 2-4 form a good transition from causal diagrams to dynamic equations.

Flow Diagrams. The relationships postulated during the conceptualization phase further can be broken down into flows of material, orders, money, personnel, capital equipment, and information. This last is considered the most important. These diagrams are explicit in their treatment of the decision structure which controls these flows (5:93-96). The diagram graphically shows the interactions between elements of the system. This graphical depiction lends a clarity to these interactions and links verbal descriptions of the system to the rate equations (5:81).

These diagrams, based on information about the system, depict relationships in terms of levels and rates. Levels can be thought of as accumulations within a system. The number of engines stocked at an air base is an example of a level. A level is determined by the difference between what is put in and what is taken out. This would be analogous to usage, in the case of, inventories or the turnover of personnel. These inputs and outputs are referred to as rates (5:68). A rate is the flow between two levels in a system and is determined by the levels they connect (5:69). In order to ascertain whether a factor is a rate or a level the system is mentally brought to a halt. If the factor still exists it is a level (5:68).

In order to make flow diagrams a better tool for depicting decision functions several, other symbols are added. These symbols are the source/sink, auxiliary variable, parameter and delay. Flow diagram symbols and definitions are shown in Figure 2-4. These symbols, when combined into a flow diagram, depict information flows, indicate where delays are encountered, identify where and how decisions are made, and how all of this affects rates.

Figure 2-3 is given as an example of a flow diagram. Items flow from a source at a certain rate (RATE1) into a level (LEV1) and through another rate (RATE2) out of the system via a sink. RATE1 is determined by LEV1, a constant (CONST) and an auxiliary (AUX1). RATE2 is determined by an auxiliary (AUX2), AUX1 and LEV1.

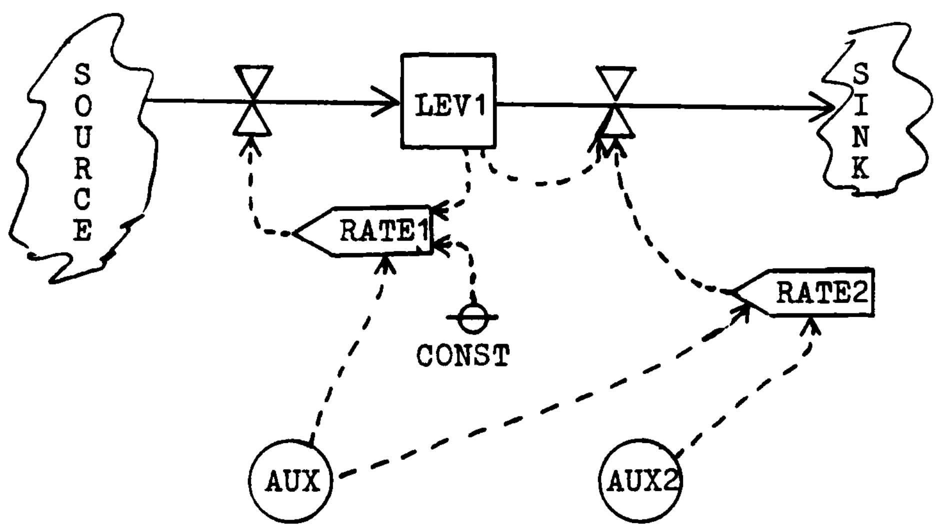
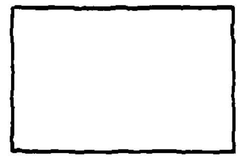


Fig. 2-3

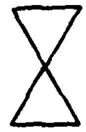
An Example of a Flow Diagram

<u>System Equations</u>. System equations, depict mathematically, the rates of flow occurring between levels of a system (5:77). These equations are developed separately for each variable and then brought together to form a

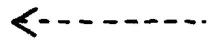
LEVELS--the value of variables which result from accumulated differences



DECISION FUNCTION (RATE)--controls the flow between levels

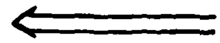


FLOWS--movements of: information



orders

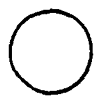
people



material

SOURCE/SINK--a source or destination outside of the system

AUXILIARY VARIABLE--adds a different meaning to a decision function



PARAMETERS--those characteristics of a system considered constant

DELAYS--represents time delays

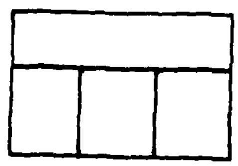


Fig. 2-4

Flow Diagramming Symbols (5:82-84)

representation of the system. As Forrester (5:140-141) notes, these equations describe those relationships which have been deemed significant. The degree of correctness or incorrectness of these equations is dependent upon the correctness or incorrectness of the perception of the system itself (5:77).

DYNAMO equations can be postulated from the flow diagram shown in Figure 2-3. The level equation for LEV1 is a relatively simple matter. This is because all level equations have the same basic structure. It can be written as follows:

```
L        LEV1.K=LEV1.J+DT*(RATE1-RATE2)
```

All level equations are written in this format (17:76; 5:143).

The rate equations are quite another matter. Rate equations are very difficult to formulate because of their nature. They can be represented by any number of mathematical relationships. One possible way to write the equation for RATE1 is:

```
R        RATE1.JK=LEV1.K+(AUX1.K*CONST)
```

This is an example of a feedback structure. The amount of material flowing through RATE1 is controlled by the amount of material in LEV1 plus the product of AUX1 and CONST. This is simply one example. Each rate equation must be based upon the relationships which the modeler finds (5:144; 17:79).

Time is depicted in DYNAMO equations by the use of subscripts. In level and auxiliary equations these subscripts are J, K, and L. They represent the past, present and future time periods respectively. Rate variables have two different subscripts. The subscript JK is used to represent the time period just past, KL is used to represent the next time period (17:68-69; 5:75-76; 6:p.5-1 to 5-2). Figure 2-5 shows the relationship between the time periods. DT stands for delta time, the amount of time which elapses between successive computations (17:68; 5:73-74; 6:p.6-3).

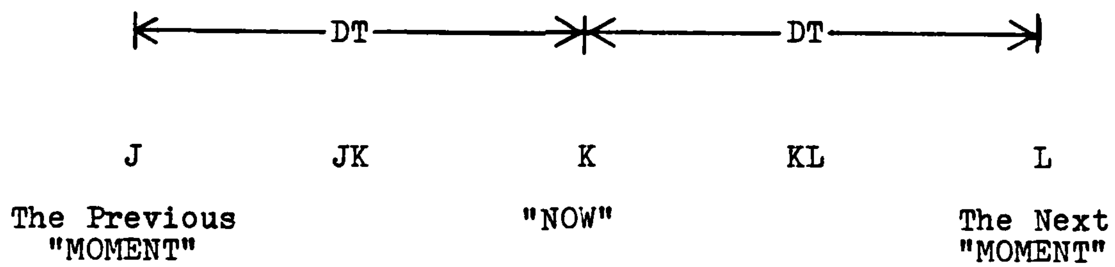


Fig. 2-5

Timescripts J, K, and L in DYNAMO (17:69)

Once the flow diagrams and system equations have been developed, the analyst is ready to begin the final stage of the systems science paradigm, computerization.

<u>Computerization</u>

The last stage of the systems science paradigm involves the computerization of the mathematical model constructed in the second phase. The DYNAMO simulation language, specially designed to ease the translation of the model to equations for use on a computer, enables a rapid feedback of the results of simulation runs. This quick turn-around time aids in deciding if the model is appropriate (2:186). The results of this final phase may lead to a reassessment of the previous steps taken. This makes the entire process iterative in nature.

Evaluation

During the final phase of the paradigm the computerized model is evaluated. This evaluation consists of verification, validation, and sensitivity analysis of the model (3; 21).

Verification. This is simply ensuring the system operates as intended. Basically, this means ensuring the computational sequence of the model is correct (21:210).

Validation. Validation of the model entails comparing model behavior to the behavior of the real world system (3:182; 21:29-30). Making this determination requires decisions be made by the analyst about how closely the behaviors are linked. Unfortunately, there is no other way to do this at the present time. The validation of a model is undoubtedly the most difficult part of a simulation experiment (14:309).

Presently a simple test for model validity does not exist (21:29; 7:209). However, there are several recognized standards. Forrester (5) has pointed out that for any one system there is an almost limitless number of valid models. The validity of any model must be judged by its purpose and how well it meets that purpose. Validity can have no meaning if it is divorced from purpose (5:115).

Forrester and Senge (7:209-229) feel that tests of model structure, model behavior and a model's policy implications all contribute to model validation. These tests serve to build confidence that the model reflects the real world system. The results of these tests can be used to instill confidence in the model in persons who were not directly involved in model construction.

In discussing validity, Coyle (3:182-184) suggests that the following questions be asked:

1. Is the boundary correct?
2. Are any gross errors apparent?
3. Does the model structure mirror reality?
4. Are the parameter values right?
5. Is system behavior reproduced by the model?

Coyle further states, that if the model has been built carefully and in conjunction with system managers the best test of validity has already been performed.

Validation of this model will be measured by how well it demonstrates the effects of changes in the flying hour program on the availability of engines at base level.

Sensitivity Analysis. Sensitivity analysis is performed by changing parameters and/or model structure in an attempt to measure the effect those changes have on model performance (5:196. In order to keep this from becoming an exercise in model use, the model must be validated. Only if the model has been validated can sensitivity analysis be used to assess the effects of changes on the system.

Summary

Discussed in this chapter was the basic methodology involved in developing a system dynamics model. The systems science paradigm, as the basis of this research, was discussed. Causal-loop or influence diagrams were presented along with flow diagrams and system equations. The chapter concluded with a discussion of the evaluation of system dynamic models.

CHAPTER 3

MODEL DEVELOPMENT

Introduction

Trichlin and Trempe (25:Ch.3) have developed a model of the Air Force reparable asset system. This model portrays the LRU/SRU relationship. An LRU, line replaceable unit, is an item which is normally removed and replaced as a unit to correct a defiency or malfunction. Spares are locally authorized to support this removal and replacement. An engine can be considered an LRU. Engines are, at times, removed and replaced to correct malfunctions. Because of the possibility of this action spare engines are authorized to be stocked at base level. An SRU, shop replaceable unit, is a module for an LRU which can be removed from the LRU at an intermediate repair facility. This makes the repair of LRUs dependent upon the stock of spare SRUs.

This study uses the General Electric J-79-17 engine as the representative LRU. The compressor section of this engine will serve as the SRU. Since both of these items must be stocked at both the base and depot level, the system can be considered a multi-item, multi-echelon system.

Overview

This chapter will detail the process of model development. The model which will be used in this study is the one developed by Trichlin and Trempe (25:Ch.3). While their model was based on an avionics component, similarities do exist between the two systems. In both the avionics repair system and the engine repair system, items are LRUs made up of SRUs. Both systems have repair capabilities in place at both base and depot levels and both require spares be stocked at base and depot level. The two systems are both multi-item, multi-echelon production and inventory systems.

One major difference is this; once an engine buy is made no additional engines are purchased (12; 13; 15; 27:p.9-1). This is not true of most spare items, additional spares can, and at times, are purchased after the initial buy. Also, because of the way engines are overhauled at the depot (on an assembly line with parts being rebuilt or remanufactured, as necessary), very few engines are lost due to condemnations. In fact, most of the engines lost to the system are due to aircraft crashes, in this case the ratio of spares to installed engines improves.

Figure 3-1 is a conceptual model of the engine management system. Each base has its own stock of serviceable engines. Through usage, these engines become unserviceable. These unserviceables can be repaired at base level or declared "not reparable this station" (NRTS)

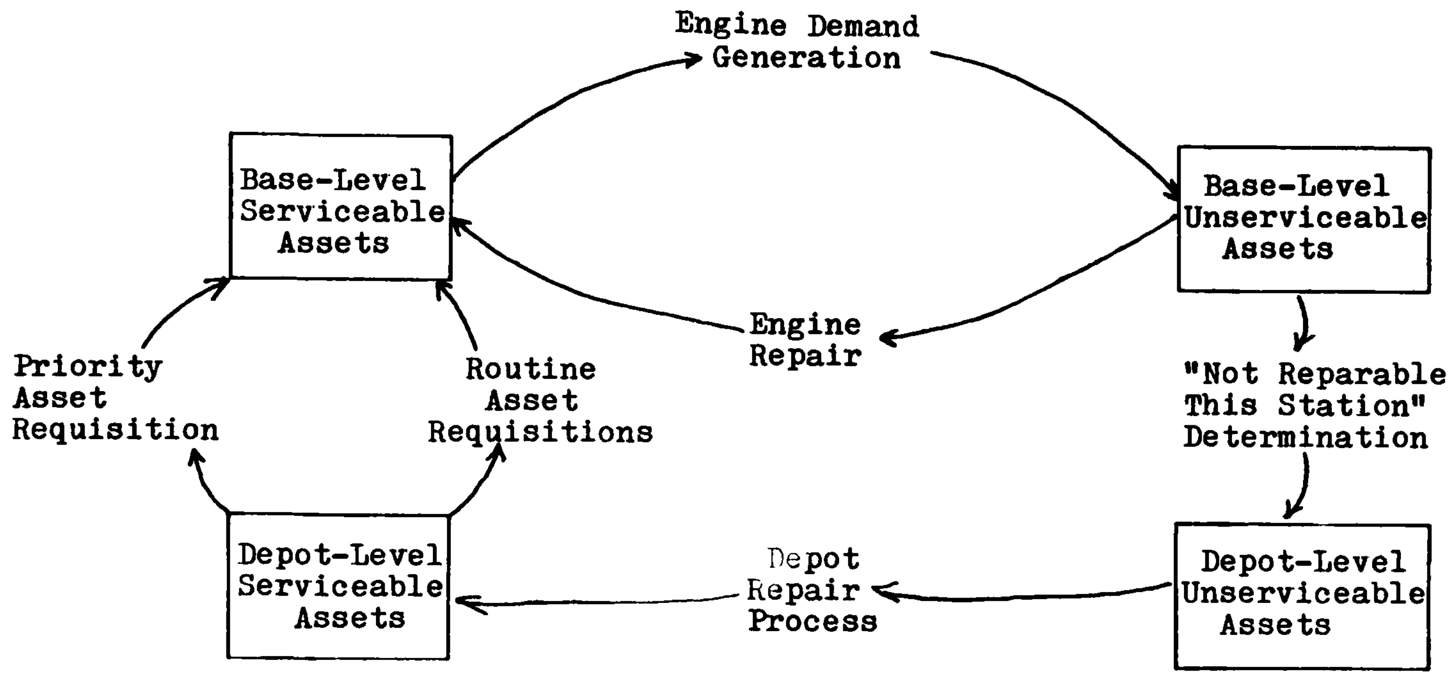


Fig. 3-1. The Air Force Engine System

and sent to the depot for repair. Engines which can be repaired, at base level, are repaired and placed in a queue to await use. Those engines which are sent to depot for maintenance are placed in an unserviceable assets inventory and via the depot repair process, they are converted to serviceable assets. They then become available for use to fill orders for engines from base level. These orders can be either routine or priority. A routine order is one needed to keep an inventory at a certain level. A priority order is one which is needed to support aircraft operations.

The model shows the way the system is set up, each component can be used to describe a sector of the overall model. The model is discussed in sectors because that is the way the model was developed. Each sector is developed as a separate entity, when the modeler is satisfied with its structure and performance he goes on to the next. Once all of the sectors are complete and working they are brought together to form the final model (17:63). Since the model was developed in sectors it is easier to describe the process of this development in sectors. For this reason, the model will be discussed in the following order:

1. Base Engine Demand Generation
2. Base Engine Repair Process
3. Base Compressor Repair
4. Quality Effects
5. Base Requisition
6. Depot Repair
7. Depot Resupply

Each sector of the model is first developed into a causal diagram. The causal diagram is then turned into a flow diagram. From the flow diagram, system equations are developed.

System Structure

In any modelling effort certain assumptions must be made. These assumptions help limit the size of the model and allow the researcher to concentrate on the area in which he is interested. This model was developed using the following structure:

1. The model deals with the interaction between only one base and the depot. This was done to avoid unnecessary complexity in the first stages of model building. It allows the basic interactions to be considered. In reality several bases interact with the depot. However, because of standardization all transactions are basically the same.

2. Only one SRU, the compressor section, is used to describe the LRU/SRU relationship. This also was done to avoid unnecessary complexity. While there are several SRUs in one engine, any malfunctioning SRU will cause an engine to malfunction. Again the interactions are basically the same.

3. This study concentrated on engines which had to be removed for maintenance. On aircraft maintenance was not considered. This was done because the objective of this research was to study the effects of pipeline times on the system.

4. No engines were allowed to leave the system. That is, no condemnations of engines were allowed, this is appropriate because engines are a "life of type" purchase and every effort is made to keep an engine in operating condition.

5. The effects of losses due to aircraft crashes was not considered. For the purpose of the model crashes were considered to be a rare event and, therefore, could be ignored.

This chapter outlines the final model development. The work is based upon the model developed by Trichlin and Trempe (25:Ch.3). Both models are representations of multi-item, multi-echelon inventory systems within the Air Force.

Base Level Engine Demand Generation

Process Description

During daily operations, an aircraft engine may be reported as malfunctioning. This report is made during post-flight maintenance debriefings. Shortly after this report a technician is dispatched to the aircraft to correct the discrepancy. At this point, the problem can be diagnosed and corrected at the aircraft or if not corrected, an engine change may be necessary. If an engine change is necessary, a demand is made on the spare engines available, and a change is made. The bad engine then moves into the base repair cycle. This demand for a replacement engine is characterized by its mean time between demand (MTBD). While the initial agent in this cycle was the mean time between failure (MTBF), it does not appear to be as important as the MTBD. MTBF is a component of MTBD but other factors also affect MTBD. The number of engines in operation, the quality of the maintenance work and the skill of the workers are some examples. The MTBD is a mean of the probability distribution of demands for that engine over time.

In considering the factors that influence MTBD, it would seem that only the utilization rate could be varied with any amount of ease. Theoretically, the usage rate of an engine could be set at any level leaving maintenance to sink or swim, either succeeding or failing to support this rate. Trichlin and Trempe (25:45) note that this rate is "usually set with the limitations" of the maintenance system as a consideration. This would indicate that system managers take many factors into consideration when setting desired usage levels.

The flying hour program is the driving factor in considering the workings of the engine management system. From the flying hour program is derived the engine use rate, the level of spares required, and the amount of man-hours needed to support a given flying hour program. For this reason the flying hour program is to be the input variable for this model.

Causal-Loop Diagram of the Engine Demand Generation Sector

Based upon the foregoing description a causal-loop diagram (Figure 3-2) of the base engine demand generation process can be drawn.

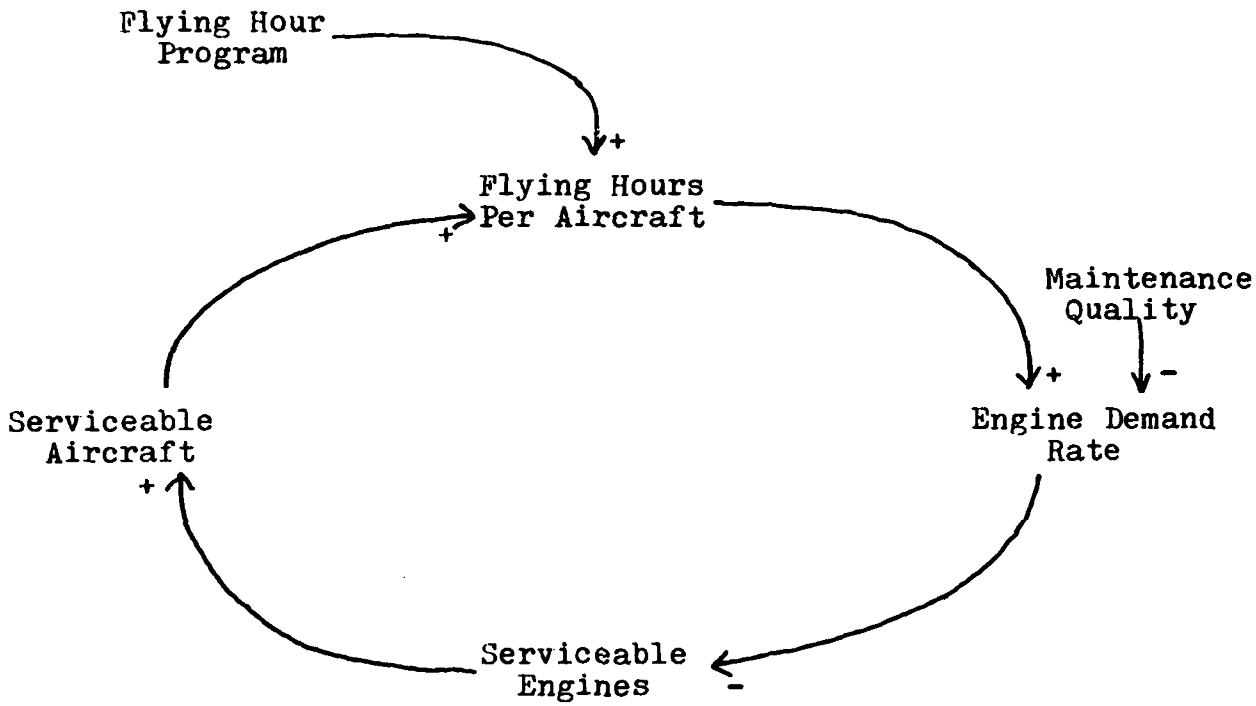


Fig. 3-2. Causal-Loop for the Engine Demand Rate Sector

The number of serviceable aircraft is directly related to the number of serviceable engines. At the same time, as more aircraft are available the average flying hours per aircraft will decrease. The flying hour program will impact directly on flying hours per aircraft. As the flying hour program goes up the number of operational hours per engine will also increase, as will the failure rate. This causes an increase in the engine demand rate. Increasing the demand for spare engines will deplete the inventory of serviceable spares.

Maintenance quality is also a determinant of the engine demand rate. However, it is a separate sector of the model and will be discussed later.

Flow Diagram for the Engine Demand Generation Sector

The flow diagram for this sector is shown in Figure 3-3.

In this sector, the level of serviceable inventory of engines (SINVE) is acted on by the rate of demand for engines (RDEM). This process turns the serviceable inventory of engines into an unserviceable inventory of engines (USINVE). Two auxiliary chains are used to help define RDEM. The rate of effort (ROE) and the mean time between demand (MTBD) chains.

The rate of effort chain begins with serviceable aircraft (SVCAC) this variable acts directly on ROE and is

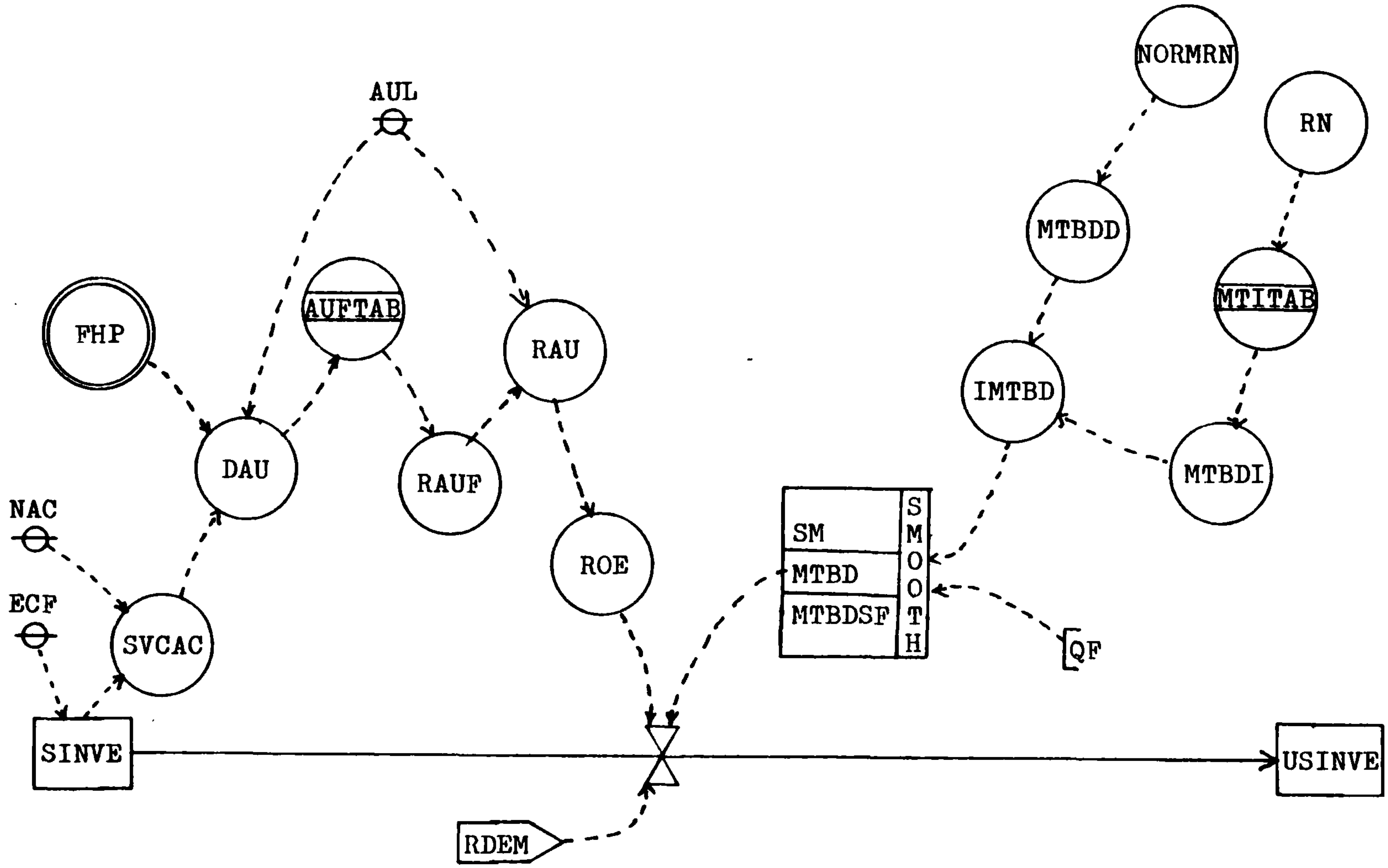


Fig. 3-3. Flow Diagram for the Rate of Demand Generation Sector

TABLE 3-1

Variables Appearing in Figure 3-3

SVCAC	-	SERVICEABLE AIRCRAFT (UNITS)
SINVE	-	SERVICEABLE INVENTORY OF ENGINES (ENGINES)
NAC	-	NUMBER OF AIRCRAFT (UNITS)
DAU	-	DESIRED AIRCRAFT UTILIZATION (FLY HR/WK/ AIRCRAFT)
FHP	-	FLYING HOUR PROGRAM (FLY HR/WK)
RAUF	-	REALIZED AIRCRAFT UTILIZATION FACTOR
AUFTAB	-	AIRCRAFT UTILIZATION FACTOR TABLE
AUL	-	ABSOLUTE UTILIZATION LIMIT (FLY HR/AIRCRAFT/WK)
RAU	-	REALIZED AIRCRAFT UTILIZATION (FLY HR/AIRCRAFT/ WK)
ROE	-	RATE OF EFFORT (FLY HR/WK)
MTBDD	-	MEAN TIME BETWEEN DEMAND DISTRIBUTION (FLY/HR)
RN	-	RANDOM NUMBER
MTBDI	-	MTBD INTERVAL (WKS)
MTITAB	-	MEAN TIME INTERVAL TABLE
IMTBD	-	INSTANTANEOUS MTBD (FLY HR)
QF	-	QUALITY FACTOR
MTBDSF	-	MTBD SMOOTHING FACTOR (WKS)
RDEM	-	RATE OF DEMAND (ENGINES/WK)
ECF	-	ENGINE CORRECTION FACTOR (ENGINES/AIRCRAFT)

acted upon by the level, SINVE, and the number of assigned aircraft (NAC), a constant. SVCAC combines with the flying hour program (FHP) to yield the desired aircraft utilization (DAU). DAU combines with the absolute utilization limit (AUL) and the aircraft utilization factor table (AUFTAB) to produce the realized aircraft utilization factor (RAUF). AUL and RAUF combine to form the realized aircraft utilization (RAU) which combines with SVCAC to yield the rate of effort (ROE).

The other auxiliary chain which defines mean time between demand (MTBD) is described as follows: The instantaneous mean time between demand (IMTBD) is determined by the mean time interval table (MTITAB) and a random number (RN) and the mean time between demand distribution (MTBDD). MTBDD is taken from a normal distribution with a mean of 560 hours and a standard deviation of 60 hours. This was obtained from the DO24F, "Propulsion Unit Actuarial Experience Computations," reports for the last five years. The IMTBD is combined with the MTBD smoothing factor (MTBDSF) and the quality factor through a smooth function to yield the mean time between demand (MTBD). The ROE and MTBD variables combine to yield the RDEM.

From this flow diagram DYNAMO equations are formed. These equations are discussed next.

DYNAMO Equations for the Engine Demand Generation Sector

Using flow diagrams as a guide, DYNAMO equations were developed. These equations will now be discussed.

The first set of equations to be considered are those which deal with the determination of serviceable aircraft.

A SVCAC.K=MIN((SINVE.K/ECF),NAC)

C NAC=72

C ECF=2

SVCAC is a minimum function because at any point in time there will never be more serviceable aircraft than the total number of aircraft assigned. Since the aircraft under consideration is the twin engine F-4, the aircraft must have two good engines to be considered serviceable. For this reason, SVCAC will be a minimum of the number of assigned aircraft and the SINVE, the total number of engines installed and spares on a base, divided by the engine correction factor (ECF). ECF is equal to two, representing two engines per aircraft. By using this constant a change can be made to allow for the study of other aircraft-engine systems. Seventy-two was chosen as the value for NAC because it represented the number of aircraft which could be found at a large wing.

The desired aircraft utilization (DAU) determination is considered next.

A DAU.K=FHP.K/SVCAC.K

Managers will wish to spread the impact of the flying hour program evenly over the entire fleet. In the long run, this probably occurs, however, in the near term some aircraft are likely to be used more often than others.

The realized aircraft utilization factor (RAUF) is taken from a table function using DAU.K/AUL as an input. As Figure 3-4 shows, as DAU.K/AUL approaches unity RAUF will increase but begin to level out at .85. The shape of this graph is intended to show that as utilization increases the realized aircraft utilization factor will also go up.

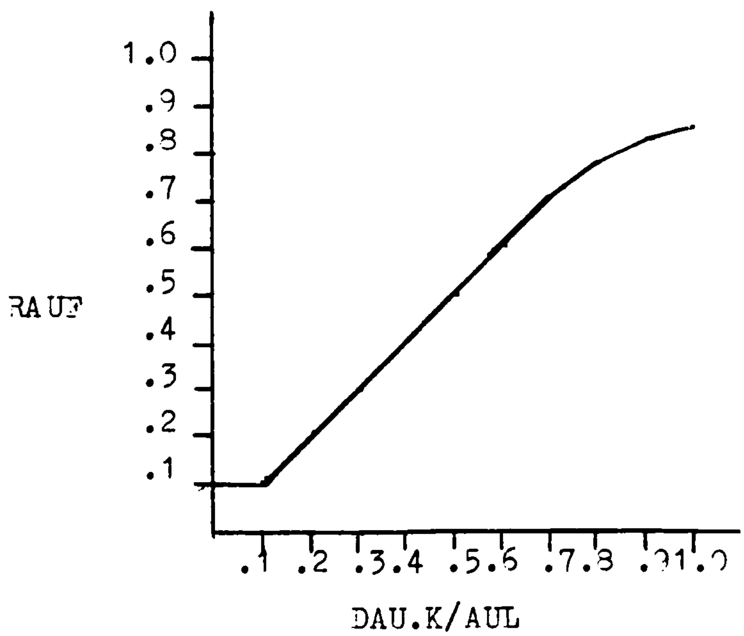


Fig. 3-4

Realized Aircraft Utilization Factor Table

However, because some aircraft will not be used as much as others, the overall usage will be around .85. This is determined by constraints such as, resources, personnel and equipment. The function has a minimum to show that there must be some low value for the flying hour program. This minimum is the lowest which would be used to justify the unit's continuing in existence.

Because the maintenance function of this system is subject to resource constraints there must be a limit on the number of flying hours per week flown. Also because several hours are needed for maintenance activities such as, refueling, post-flight inspection, and unscheduled maintenance, an absolute utilization limit (AUL) is set. The value of AUL will be 25 hours per week.

The next equation which will be considered is the realized aircraft utilization (RAU). It is obtained by multiplying AUL by RAUF.

```
A        RAU.K=RAUF.K*AUL
```

The auxiliary, rate of effort (ROE), is derived from an information delay, DLINF3, of RAU multiplied by SVCAC delayed over one week. As the number of serviceable aircraft goes up ROE will go down and vice versa. It takes less effort to do the same amount of flying with more aircraft, all other things being equal.

The mean time between demand distribution (MTBDD) is taken from the NORMRN macro. It uses an average mean time between demand of 560 hours with a standard deviation of 60 hours. These values were obtained from the DO24F, report of engine removals, for the past five years.

```
A         MTBDD.K=NORMRN(560,60)
```

Also in this sector, a random number (RN) is generated using the noise function. This random number is used as the input function for the mean time between demand interval (MTBDI). The mean time interval table (MTITAB) causes a random number to be held for from four to twelve weeks of simulation time. If the value of RN is less than or equal to zero the MTBDI will be held for four weeks. If it is greater than zero MTBDI will be held for twelve weeks.

The sample macro allows an instantaneous MTBD to be drawn from MTBDD, MTBDI, and 560 hours.

```
A         RN.K=NOISE()
A         MTBDI.K=TABLE(MTITAB,RN.K,-.5,.5,.5,1)
T         MTITAB=4/12
A         IMTBD.K=SAMPLE(MTBDD.K,MTBDI.K,560)
```

MTBD is derived by multiplying the quality factor (QF) by the smoothed IMTBD. The smoothing factor (MTBDSF) is five weeks. Five weeks is a sufficient amount of time to avoid abrupt changes in MTBD.

```
A         MTBD.K=QF*(SMOOTH(IMTBD.K,MTBDSF))
C         MTBDSF=5
```

The MTBD and ROE chains are used to derive the rate of demand (RDEM). RDEM is obtained by dividing ROE by MTBD.

Discussed in this section was the development of the demand generation sector. The next section will discuss the development of the engine repair sector.

Base Engine Repair Process

Process Description

In this sector, the process of repairing unserviceable engines and returning them to the serviceable engine inventory is discussed. Because of flying activities, engines fail and are replaced by serviceable engines. This cycle decreases the number of serviceable engines and increases the number of unserviceables on a base at any given time. An increase in the unserviceable inventory will cause a manager to increase shop work rates in an attempt to return unserviceable engines to the serviceable inventory. Because of the manner in which the system is set up, with a greater repair capability at the depot, a certain percentage of engines will be declared "not reparable this station" (NRTS) and returned to the appropriate ALC for repair.

Causal-Loop Diagram of the Base Engine Repair Process

Figure 3-5 is a causal-loop diagram of the above process description. The engine demand rate derived in the previous sector is the input for this sector. As the

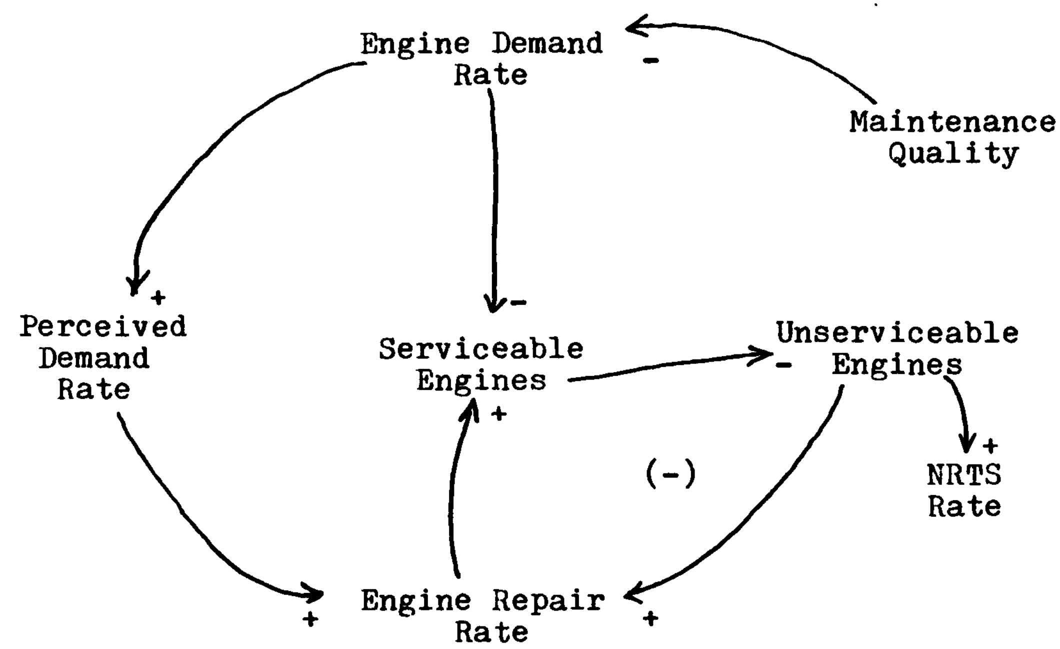


Fig. 3-5. Causal-Loop Diagram for Base Engine Repair Process

demand for engines goes up, the number of serviceable engines goes down and the number of unserviceable engines goes up. The engine repair rate will go up because of the increase in unserviceable engines. This assumes there are sufficient repair bays and personnel. This point will be discussed more fully in the flow diagrams for this sector. This increase in the repair rate will drive down the number of unserviceable engines. A change in the engine repair rate will also be affected by management's perception of the engine demand rate. Additionally, as the number of unserviceable engines increases the number of engines declared NRTS will increase. However, the percentage of engines declared NRTS will remain the same. Changes in the engine repair rate may have a negative impact on quality, especially if an attempt is made to shorten the cycle time.

Flow Diagram for the Base Engine Repair Process

The flow diagram for this sector is shown in Figure 3-6.

The driving input to this sector is the rate of demand (RDEM) derived in the first sector. This rate of demand feeds into a third-order information delay which yields the perceived demand rate (PDR). This variable, PDR, is used because the perception of an occurrence is as important as the actual event. It also takes a certain

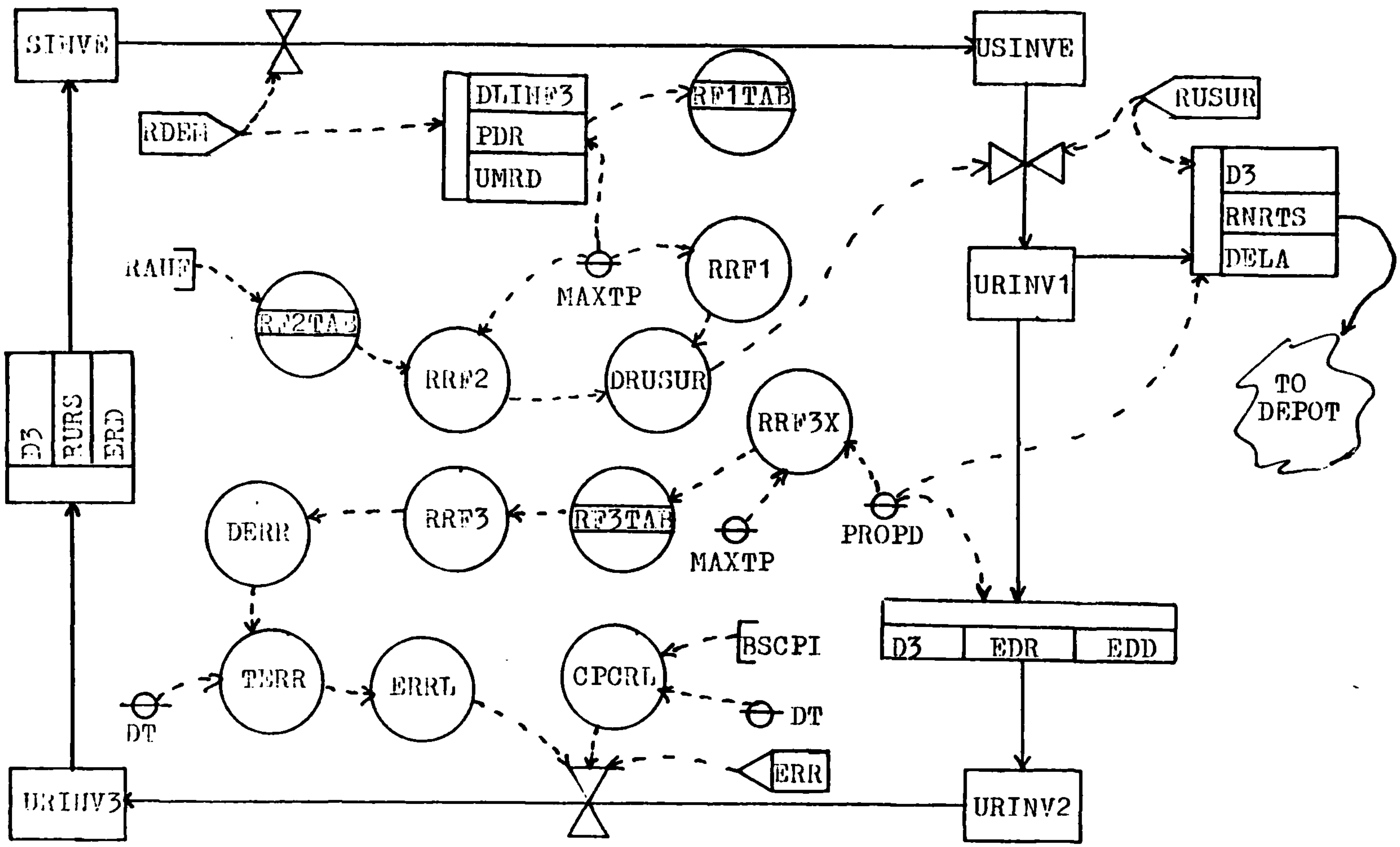


Fig. 3-6. Flow Diagram for Base Engine Repair Process Sector

TABLE 3-2

Variables Appearing in Figure 3-6

SINVE -	SERVICEABLE ENGINE INVENTORY (ENGINES)
RDEM -	RATE OF DEMAND (ENGINES/WK)
PDR -	PERCEIVED DEMAND RATE (ENGINES/WK)
UMRD -	UNIT MAINTENANCE RESPONSE DELAY (WKS)
RF1TAB -	REPAIR RATE FACTOR ONE TABLE
RRF1 -	REPAIR RATE FACTOR ONE
MAXTP -	MAXIMUM THROUGHPUT (ENGINES/WK)
RAUF -	REALIZED AIRCRAFT UTILIZATION FACTOR
RF2TAB -	REPAIR RATE FACTOR TWO TABLE
RRF2 -	REPAIR RATE FACTOR TWO
DRUSUR -	DESIRED RATE UNSERVICEABLES GO UNDER REPAIR (ENGINES/WK)
RUSUR -	RATE UNSERVICEABLES GO UNDER REPAIR (ENGINES/WK)
USINVE -	UNSERVICEABLE INVENTORY OF ENGINES (ENGINES)
URINV1 -	UNDER REPAIR INVENTORY ONE (ENGINES)
PROPD -	PROPORTION OF ENGINES TO DEPOT
RNRTS -	RATE ENGINES DECLARED NRTS (ENGINES/WK)
DELA -	DELAY FOR NRTS ASSESSMENT (WKS)
RRF3X -	REPAIR RATE FACTOR THREE INDEX
RF3TAB -	REPAIR RATE FACTOR THREE TABLE
RRF3 -	REPAIR RATE FACTOR THREE
DERR -	DESIRED ENGINE REPAIR RATE (ENGINES/WK)
DT -	DELTA TIME (WKS)
TERR -	TRIAL ENGINE REPAIR RATE (ENGINES/WK)
ERRL -	ENGINE REPAIR RATE LIMIT (ENGINES/WK)
CPCRL -	COMPRESSOR CONSUMPTION RATE LIMIT (COMPRESSORS/WK)
BSCPI -	BASE SERVICEABLE COMPRESSOR INVENTORY (COMPRESSORS)
ERR -	ENGINE REPAIR RATE (ENGINES/WK)
EDR -	ENGINE DIAGNOSIS RATE (ENGINES/WK)
EDD -	ENGINE DIAGNOSIS DELAY (WKS)
URINV2 -	UNDER REPAIR INVENTORY TWO (ENGINES AWAITING COMPRESSORS)
URINV3 -	UNDER REPAIR INVENTORY THREE (ENGINES)
RURS -	RATE UNSERVICEABLES RETURN TO SERVICE (ENGINES/WK)
ERD -	ENGINE REPAIR DELAY (WKS)

amount of time to recognize what is happening in a system.

Because of an increase in demand pressure managers will feel compelled to increase the repair rate. An attempt is made to capture this pressure in the variable, repair rate factor one (RRF1).

This repair rate factor is derived by combining PDR with the maximum throughput (MAXTP) and the repair rate factor one table (RF1TAB). A MAXTP is needed because in reality there are restrictions on the maintenance repair capability. This study uses a complex with four maintenance bays and sufficient numbers of tools and personnel to man the four bays. It is felt that the most engines such a complex could turn out would be an average of two per week. This figure is used because it takes two weeks to turn out an engine at base level. The shape of the repair rate factor one table (RF1TAB) will be more fully explained in the sector on system equations.

As the serviceable engine inventory is drawn down, managers begin to feel pressure to increase the repair rate for engines. This repair rate, repair rate factor two (RRF2), is derived when the realized aircraft utilization factor (RAUF) is used as an input to the repair rate factor two table (RF2TAB). RAUF is used as an input because as the use rate for aircraft goes up more engines will be removed for maintenance, causing the serviceable inventory of engines to decrease.

RRF1, RRF2, and MAXTP combine to yield the desired rate unserviceables go under repair (DRUSUR). This desired rate combines with the unserviceable inventory of engines to yield the rate unserviceables actually go under repair (RUSUR). RUSUR separates the unserviceable inventory from the under repair inventory one (URINV1). URINV1 is one of three under repair inventories. It represents the delay engines experience during diagnosis. URINV1 has two outflow rates. The first, the rate engines are declared NRTS (RNRTS), goes to the depot repair process. The second, the engine diagnosis rate (EDR), flows into the second under repair inventory (URINV2). URINV2 represents those engines which must wait for a compressor before repairs can be completed.

From URNIV2, engines flow into the third under repair inventory (URINV3) at a rate equal to the engine repair rate (ERR). ERR is derived from an auxiliary chain and will be described more fully in the section on system equations. URINV3 represents the final stage of maintenance, testing to insure the engine will operate satisfactorily. From URINV3, engines are returned to the serviceable inventory via a third-order delay, the rate unserviceables return to service (RURS).

This section has discussed the flow diagram for the base engine repair process sector. From this flow diagram DYNAMO equations are developed.

DYNAMO Equations for the Base Engine Repair Process

The DYNAMO equations derived from the flow diagram shown in Figure 3-6 are presented here. Following the same pattern as the discussion of the flow diagrams, the perceived demand rate is discussed first.

A third-order information delay using the rate of demand (RDEM) as an input yields the perceived demand rate. This is used in an attempt to capture the delay between when an event actually occurs and the perception of what actually happened. The unit maintenance response delay is set at 0.2 weeks, a little more than a day and a half, to represent the time it takes to perceive how many engines are being demanded.

PDR is then divided by MAXTP and used as an input to the repair rate factor one table (RF1TAB). The output of this table is the repair rate factor one (RRF1). As mentioned earlier, this represents the pressure managers feel to increase work rates due to demand.

RF1TAB is shown in Figure 3-7. This table is constructed in an attempt to show how managers increase work rates in response to demand pressures. The minimum is set at 0.5 to indicate that even when there is little or no work to be done on engines, the workers will still be put to some use. This minimum could have been set at any level. In the real system it is likely that it varies

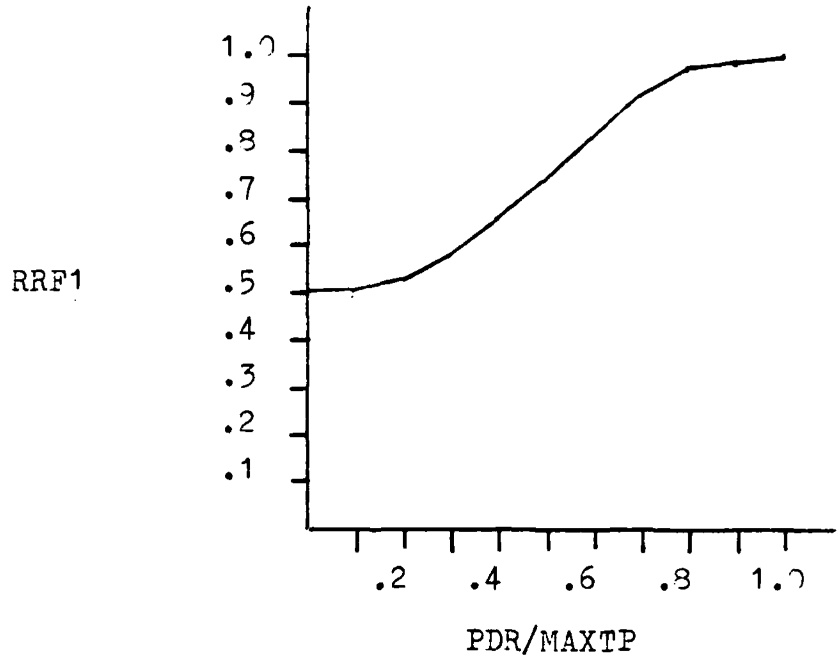


Fig. 3-7 Table for Repair Factor One

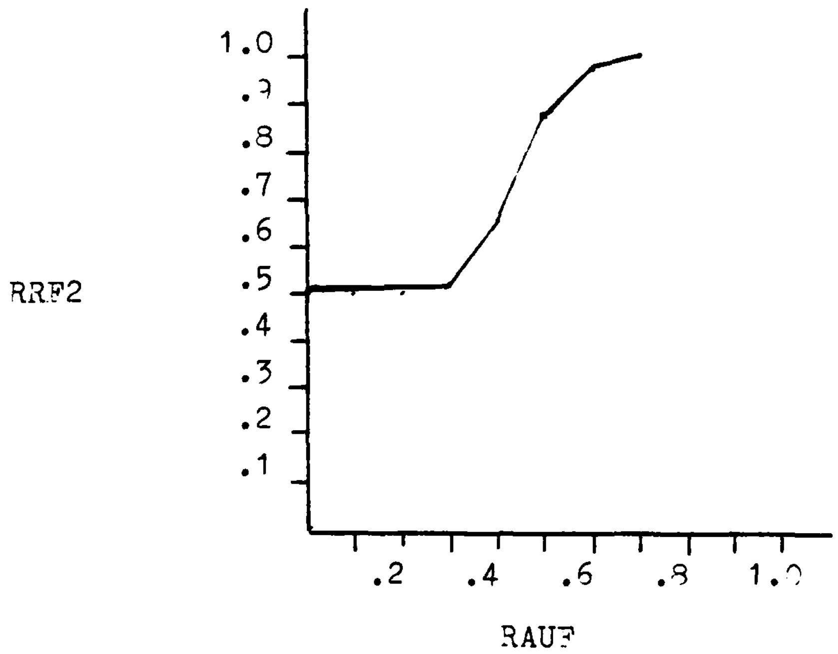


Fig. 3-8 Table for Repair Factor Two

and may even go to zero, with stand-down days for example.

A PDR.K=DLINF3(RDEM.K,UMRD)

C UMRD=0.2

A RRF1.K=TABHL(RF1TAB,(PDR.K/MAXTP),0,1,.1)

T RF1TAB=.5/.5/.53/.58/.65/.73/.82/.91/.97/.98/1.0

The second repair rate factor (RRF2) is obtained by inputting the realized aircraft utilization factor (RAUF) into the repair rate factor two table (RF2TAB). This table is an attempt to capture the pressure managers feel to increase work rates due to inventory level pressures. As the serviceable inventory is drawn down managers will feel compelled to increase the amount of work being done on engines. The table, shown in Figure 3-8, is only slightly different from RF1TAB. This is because of the different pressures felt by managers due to inventory levels. Again the table starts at .5 for the same reason that RF1TAB started at .5.

A RRF2.K=TABHL(RF2TAB,RAUF.K,0,.7,.1)

T RF2TAB=.5/.5/.5/.52/.66/.88/.99/1.0

The two repair rate factors are both multiplied by the maximum throughput (MAXTP) The larger of the two products is used as the desired rate unserviceables go under repair (RUSUR). This is done by using the MAX function, which returns the larger of the two values as the value of DRUSUR. This structure is used to allow the higher repair rate to be used.

A DRUSUR.K=MAX(RRF1.K*MAXTP,RRF2.K*MAXTP)

C MAXTP=2.0

The DRUSUR value is then used to obtain the rate unserviceables go under repair (RUSUR). In dealing with an inventory as important as the engine inventory is to capability, managers will wish to repair malfunctioning units as quickly as possible, thus the choice made here represents the higher of the two rates.

R RUSUR.KL=FIFGE(USINVE/DT,DRUSUR.K,DRUSUR.K,
USINVE/DT)

The FIFGE macro will take the First value IF the third is Greater than or Equal to the fourth, otherwise, it will return the second (12:119). In this case RUSUR will either be USINVE/DT or DRUSUR depending upon the conditions.

The unserviceable inventory of engines (USINVE) is determined by the following equation:

L USINVE.K=USINVE.J+DT*(RDEM.JK-RUSUR.JK-DTDR.JK)

Unserviceable engines come into the inventory at a rate equal to RDEM and leave the inventory by two means. The first is the rate unserviceables go under repair. The second is the diversion to depot rate, the number of engines per week that are sent to the depot. This is done to show that engines can be repaired by two processes, also included in this are those engines which meet their maximum operating limits and are removed to be shipped to depot for overhaul.

The under repair inventory is broken into three levels. Those which are being processed or diagnosed, (URINV1), those engines which are awaiting compressor sections to complete repair actions, and those which are actually being repaired, this section includes those engines which are being tested to insure they are in serviceable condition.

URINV1 is determined by the following equation:

L URINV1.K=URINV1.J+DT*(RUSUR.JK-RNRTS.JK-EDR.JK)

During the diagnosis process it is discovered that some engines are beyond the repair capability of the base. These engines are declared NRTS at a rate equal to RNRTS. The other outflow of the level, EDR, is shown as a third-order delay.

RNRTS is the output of a third-order delay. It is obtained by multiplying the proportion of engines to depot (PROPD) by (RUSUR). This is done to show that the proportion of engines being sent to depot will be constant but the actual numbers of engines will change. RNRTS is delayed over the engine diagnosis delay of 1.1 weeks. This is the standard amount of time allowed for diagnosis of engine malfunctions. The RNRTS equation is as follows:

R NRTS.KL=DELAY3(PROPD*RUSUR.JK,DELA)

C DELA=1.1

The engine diagnosis rate is derived from the following third-order delay equation:

R EDR.KL=DELAY3((1-PROPD)*RUSUR.JK,EDD)

C EDD=0.28

This rate captures engines coming into the base repair process. One minus PROPD is used to indicate that only those engines which are to be repaired at base level are considered here. This value is multiplied by RUSUR to show that this rate is a function of the number of engines being sent into the repair process.

The inventory of engines awaiting compressor units is depicted by the following equation:

L URINV2.K=URINV2.J+DT*(EDR.JK-ERR.JK)

This level equation is the same as for all level equations. The change rate of the equation is equal to the difference between EDR and ERR.

The engine repair rate is derived from an auxiliary chain which starts with repair rate factor three index. This repair rate symbolizes the rate that engines are actually repaired. It begins with the repair rate factor three index (RRF3X). This index is obtained by dividing EDR by 1-PROPD*MAXTP. RRF3X is used as an input to the repair rate factor three table (RF3TAB), and yields the third repair rate factor (RRF3). RRF3 is a function of the number of engines being diagnosed. RF3TAB is shown in Figure 3-9. It is related to the table for RRF1 as follows:

.625=RRF1(MIN)/(1-PROPD)

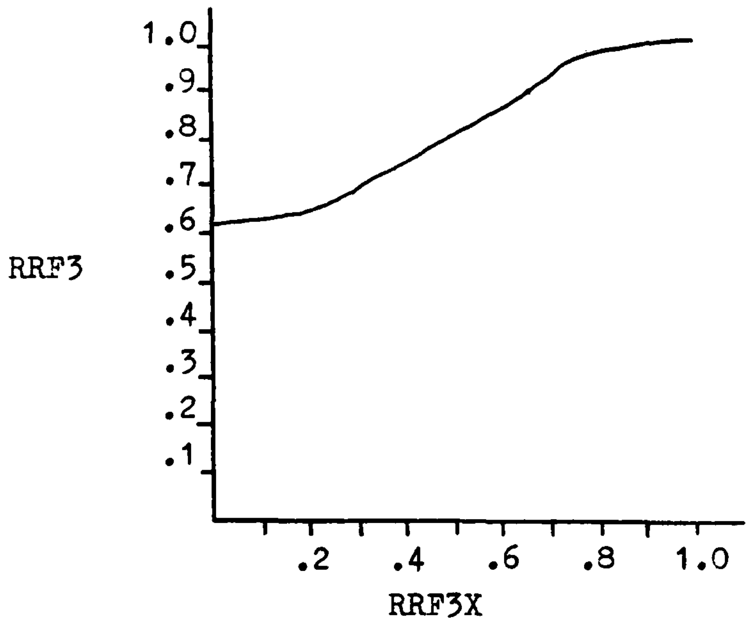


Fig. 3-9

Table for Repair Rate Factor Three

Again the minimum could have been set at any level, but since engines will be arriving at this point if there are activities going on in the preceding stages this seems to be a reasonable formulation.

RRF3 is multiplied by one minus PROPD and MAXTP to yield the desired engine repair rate (DERR). This is to show that this rate will be a function of RRF3, the number of engines staying on base for repair, and the maximum number of engines which can be repaired in a week.

The value for DERR is then used in a FIFGE macro with USINV2.K/DT to yield the trial engine repair rate (TERR).

The compressor consumption rate limit (CPCRL) will be equal to the base serviceable compressor inventory (BSCPI) divided by delta time (DT). This is used because managers will want to spread their usage of spares over time rather than all at once.

The engine repair rate limit (ERRL) is constructed as another FIFGE macro. In this case, the compressor consumption rate limit (CPCRL) divided by the compressor generation factor (CPGF) or the test engine repair rate, whichever is appropriate is used. From these equations the engine repair rate (ERR) is derived. The purpose of the entire string is to show that the repair of engines will be a function of the number of engines going into the repair process and the number of compressors available to the repair process. The string of equations which are used to derive the engine repair rate are listed below:

```
A          RRF3X.K=EDR.JK/((1-PROPD)*MAXTP)

A          RRF3.K=TABHL(RF3TAB.RRF3X.K,0,1,.1)

T          RF3TAB=.625/.635/.66/.71/.77/.83/.88/.95/.99/1.0

A          DERR.K=RRF3.K*(1-PROPD)*MAXTP

A          TERR.K=FIFGE(URINV2.K/DT,DERR.K,DERR.K,
               URINV2.K/DT)

A          CPCRL.K=BSCPI.K/DT

A          ERRL.K=FIFGE(CPCRL.K/CPGD,TERR.K,TERR.K,CPCRL.K/
               CPGF)

R          ERR.KL=ERRL.K
```

N ERR=0

The third under repair inventory (URINV3) is a level whose change rate is the engine repair rate (ERR) minus the rate unserviceables return to service (RURS). This inventory represents those engines which are in the process of being tested to assure they are ready to be returned to service. Its outflow, RURS, is a third-order delay of the engine repair rate (ERR) over the engine repair delay of two weeks. This is the standard amount of time allowed for the repair of engines at base level. The equations for URINV3 and RURS are listed below:

```
L        URINV3.K=URINV3.J+DT*(ERR.JK-RURS.JK)
N        URINV3=0
R        RURS.KL=DELAY3(ERR.JK,ERD)
C        ERD=2
```

The final equations to be discussed in this sector are those which deal with the serviceable inventory of engines (SINVE). The equations are listed here:

```
L        SINVE.K=SINVE.J+DT*(RURS.JK+RARFD.JK+
             RAPFD.JK-RDEM.JK)
N        SINVE=BE
C        BE=151
```

As shown the change rate of the SINVE equation is the sum of the rate unserviceables return to service and the arrival of shipments from depot, both routine (RARFD) and priority (RAPFD), minus the rate of demand for serviceable engines (RDEM).

SINVE is set equal to base engines (BE) initially to allow use of DYNAMO's rerun option. This option allows parameter changes to be made without recompiling the entire program, a considerable saving of time. Base engines is set equal to 151 engines, 144 engines installed plus 7 engines at base level for use as spares.

This sector has dealt with the repair of engines at base level. The next sector will deal with the repair of engine compressors at base and depot level.

Compressor Repair

The engine system cannot be considered in depth unless the interaction of shop replaceable units (SRUs) with the engine is considered. If a modeler chose not to consider this relationship the following assumptions would be necessary:

1. No SRUs are contained in the component. This is not true when considering engines. All engines are made up of SRUs.

2. The availability, or lack of availability, of SRUs will not affect the repair rate. This cannot be assumed to be true in the engine system. If an SRU is not available when needed the engine cannot be repaired.

3. The SRU repair delay can be incorporated in the LRU delay adequately. That is, the delay caused by the SRU process will not significantly affect the LRU in question. In the engine management system this is

not true. If compressors are not available in sufficient numbers, then engines will be delayed in the repair process.

Since none of the above conditions exist the interaction between compressor sections and engines must be considered.

Process Description of the Compressor Repair Process

The first step in the process is the diagnosis of a faulty compressor and removal of the compressor from the engine. The second step is the replacement of the faulty compressor in the engine and the return of that engine to the serviceable inventory; any calibration required is incorporated in this step. Engines are held in an under repair inventory awaiting compressors between steps one and two.

Causal-Loop Diagram of the Compressor Repair Process

The causal-loop diagram for this sector is shown in Figure 3-10. The relationship between serviceable engines and unserviceable engines is negative. As the number of serviceable engines decreases the number of unserviceable engines will increase and vice versa. This increase in the number of unserviceable engines will cause an increase in the number of engines awaiting a compressor unit. As the number of compressors worked on

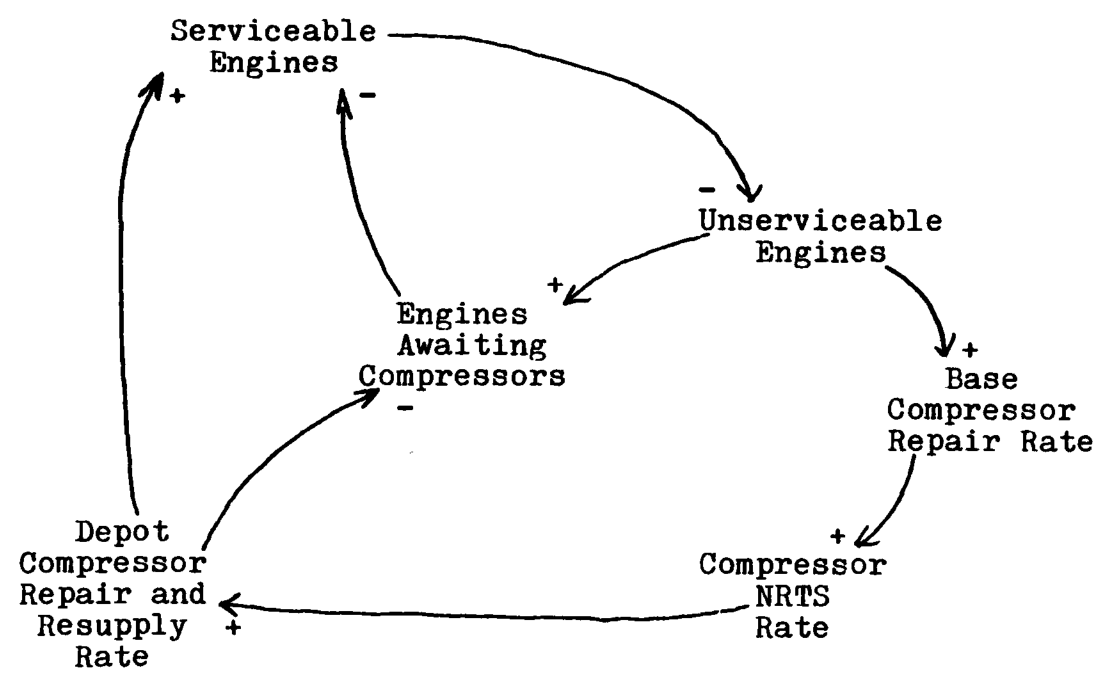


Fig. 3-10. Causal-Loop Diagram for Base Compressor Repair Process

at base level increase the number of compressors declared "not reparable this station" (NCPR) will also go up. The increased NRTS rate will cause the depot repair and resupply to increase. Both the depot repair and resupply rate and the base compressor repair rate will have a negative impact on the number of engines awaiting compressor units. Finally, as the number of engines awaiting compressors is decreased the number of serviceable engines will be increased.

The causal-loop diagram for this sector now can be turned into a flow diagram. This flow diagram will be discussed next.

Flow Diagram of the Compressor Repair Process

The flow diagram for this sector is shown in Figure 3-11.

Compressor arrive at the unserviceable compressor inventory (USCPI) at some rate. This rate, the reparable compressor rate (RCPR), is determined by the engine diagnosis rate (EDR) and the compressor generation factor (CPGF).

The rate compressors go under repair (RCPUR) is the rate at which compressors move into the base unserviceable compressors inventory. This rate is determined by the level of USCPI, the computation interval, the maximum throughput of compressors (MTPCP) and the

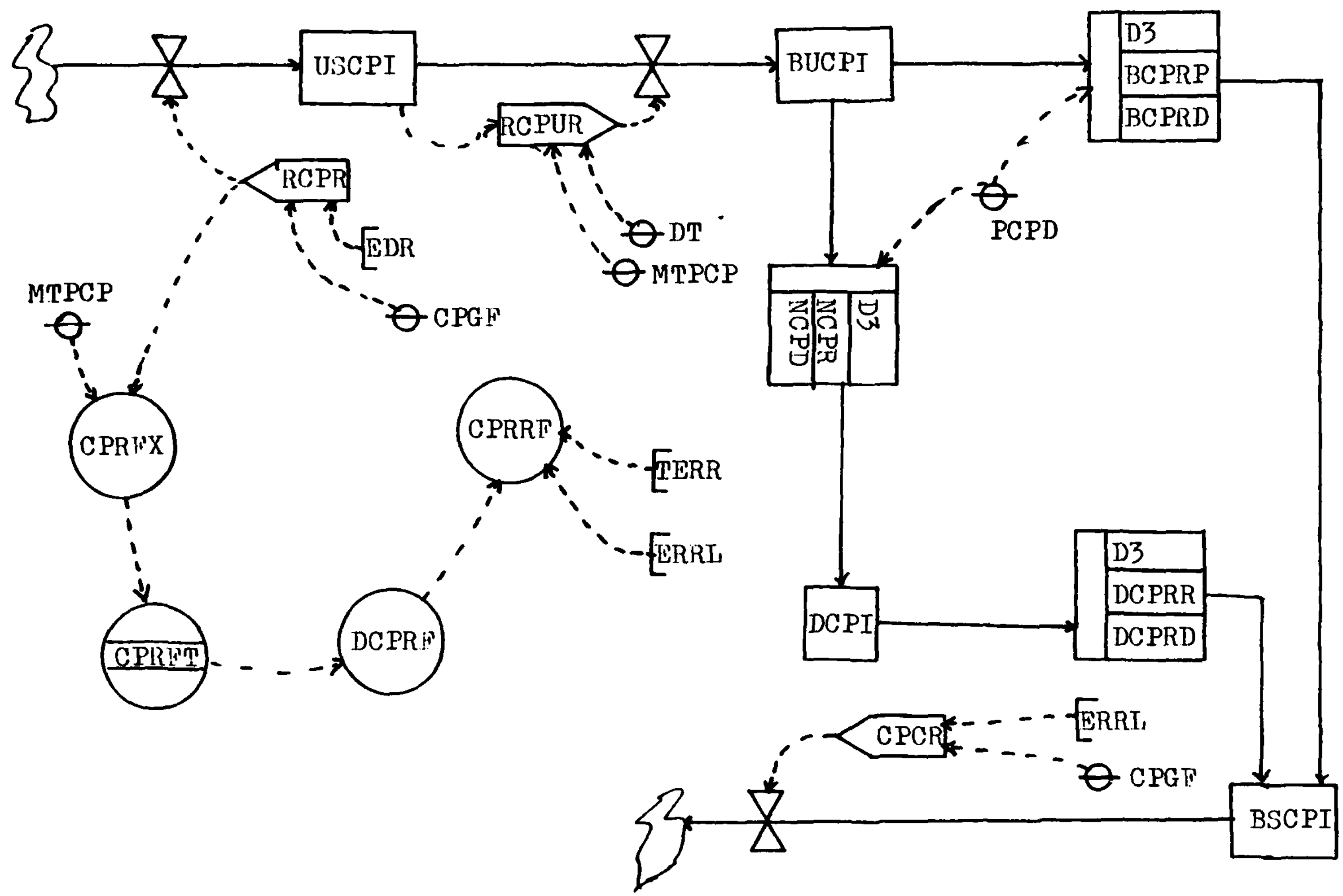


Fig. 3-11. Flow Diagram of the Compressor Repair Process

TABLE 3-3

Variables Appearing in Figure 3-11

EDR	-	ENGINE DIAGNOSIS RATE (ENGINES/WK)
CPGF	-	COMPRESSOR GENERATION FACTOR (COMPRESSORS/ ENGINE)
RCPR	-	REPARABLE COMPRESSOR RATE (COMPRESSORS/WK)
MTPCP	-	MAXIMUM THROUGHPUT OF COMPRESSORS (COMPRESSORS/ WK)
CPRFX	-	COMPRESSOR REPAIR FACTOR INDEX
CPRFT	-	COMPRESSOR REPAIR FACTOR TABLE
DCPRF	-	DEPOT COMPRESSOR REPAIR FACTOR
USCPI	-	UNSERVICEABLE COMPRESSOR INVENTORY (COMPRESSORS)
DT	-	DELTA TIME (WKS)
RCPUR	-	RATE COMPRESSORS GO UNDER REPAIR (COMPRESSORS/WK)
CPRRF	-	COMPRESSOR REPAIR RATE FACTOR
TERR	-	TRIAL ENGINE REPAIR RATE (ENGINES/WK)
ERRL	-	ENGINE REPAIR RATE LIMIT (ENGINES/WK)
BUCPI	-	BASE UNSERVICEABLE COMPRESSOR INVENTORY (COMPRESSOR)
PCPD	-	PROPORTION OF COMPRESSORS TO DEPOT
BCPRR	-	BASE COMPRESSOR REPAIR RATE (COMPRESSORS/WK)
BCPRD	-	BASE COMPRESSOR REPAIR DELAY (WKS)
NCPR	-	RATE COMPRESSORS DECLARED NRTS (COMPRESSORS/WK)
NCPD	-	NRTS COMPRESSOR ASSESSMENT DELAY (WKS)
DCPI	-	DEPOT COMPRESSOR INVENTORY (COMPRESSORS)
DCPRR	-	DEPOT COMPRESSOR REPAIR RATE (COMPRESSORS/WK)
DCPRD	-	DEPOT COMPRESSOR REPAIR DELAY (WKS)
BSCPI	-	BASE SERVICEABLE COMPRESSOR INVENTORY (COMPRESSORS)
CPCR	-	COMPRESSOR CONSUMPTION RATE (COMPRESSOR/WK)

compressor repair rate factor (CPRRF).

At this point the BUCPI is divided into two separate quantities. One of the quantities represents those compressors which are repaired at base level. A third-order delay represents the base compressor repair rate (BCPRR). This is derived from the rate compressors go under repair (RCPUR) and the proportion of compressors sent to depot (PCPD). BCPRR moves compressors into the base serviceable compressor inventory after a delay of two weeks. This is the standard amount of time it takes to repair a compressor at base level. The remainder of the compressors undergo a third-order delay to be declared NTRS, this rate is also determined by PCPD and RCPUR, and move into the depot compressor inventory. A third-order delay, the depot compressor repair rate, (CDPRR), characterizes the depot level compressor repair process. The DCPRR is determined by the depot compressor inventory and the rate compressors are declared NRTS. After the depot compressor repair delay (DCPRD) of six weeks compressors move back into the base serviceable compressor inventory (BSCPI).

These same compressors move out of the serviceable compressor inventory (BSCPI) at a rate, the compressor consumption rate (CPCR), determined by the engine repair rate limit, and the compressor generation factor (CPGF).

This flow diagram is the basis for the development of DYNAMO equations. These equations are discussed next.

DYNAMO Equations for the Compressor Repair Process

The reparable compressor rate (RCPR) is the rate compressors which need repair are generated. It is equal to the engine diagnosis rate (EDR) multiplied by the compressor generation factor (CPGF). This set of equations was set up to show the number of compressors which are generated by unserviceable engines. The equations for RCPR are listed below:

```
R         RCPR.KL=EDR.JK*CPGF
C         CPGF=0.40
```

The unserviceable compressor inventory (USCPI) is a level determined by the change rate RCPR minus RCPUR. RCPUR is defined as the rate compressors go under repair. The compressors in this inventory are those which are taken off of engines which are being repaired. The equations for USCPI are listed next.

```
L         USCPI.K=USCPI.J+DT*(RCPR.JK-RCPUR.JK)
N         USCPI=0
```

The reparable compressor rate, when divided by the maximum throughput of compressors (MTPCP), yields the compressor repair factor index. This index, CPRFX, is used as an input to the compressor repair factor table (CPRFT) to give the desired compressor repair factor

(DCPRF). This equation is used to indicate managers will repair compressors as they come in up to the limit for that repair rate.

The compressor repair factor table starts at .5. This is the same as the repair rate factor one table (RF1TAB) and the same reasoning is used here. That is, even when there is little or no repair work to be done the workers will be put to some use. In truth this table could have any minimum value. CPRFT moves from .5 to unity as CPRFX moves from zero to unity. The relationship is as shown in Figure 3-12.

The desired compressor repair factor (DCPRF) is combined with the trial engine repair rate (TERR) and the engine repair rate limit (ERRL) to yield the compressor

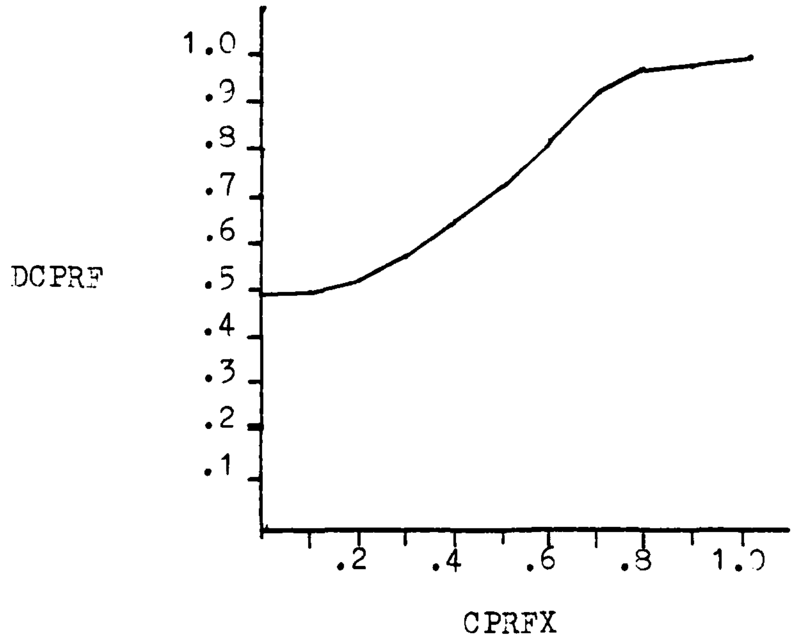


Fig. 3-12 The Compressor Repair Factor Table

repair rate factor (CPRRF). This is accomplished by using the FIFZE macro, FIFZE is a mnemonic for First IF third is equal to ZEro (12:119), in this usage the macro will return the current value of DCPRF or one, whichever is appropriate, as the value of the compressor repair rate factor (CPRRF). This equation is designed to show that if TERR minus ERR is zero then CPRRF will be equal to the DCPRF, otherwise it will be one. This becomes important in the equation for the rate compressors go under repair.

The rate equation which defines RCPUR is a FIFGE macro, First IF third is Greater than or Equal to the fourth. This means that managers will set some average work rate based on the inventory of unserviceables or they will work at some greater rate up to the maximum workload. The choice depends on the pressure exerted by the present level of activities. The equations which lead to the determination of RCPUR are shown below.

```
A         CPRFX.K=RCPR.JK/MTPCP
C         MTPCP=5
A         DCPRF.K=TABHL(CPRFT,CPRFX.K,0,1,.1)
T         CPRFT=.5/.5/.53/.58/.65/.73/.82/.91/1.0
A         CPRRF.K=FIFZE(DCPRF.K,1,TERR.K-ERR.K)
R         RCPUR.KL=FIFGE(USCPI/DT,CPRRF.K*MTPCP,
              CPRRF.K*MTPCP,USCPI.K/DT
```

The base unserviceable compressor inventory (BUCPI) is determined by subtracting the base compressor repair rate (BCPRR) and the rate compressors declared NRTS

(NCPR) from the rate compressors go under repair (RCPUR). The level equation for BUCPI is as follows:

```
L        BUCPI.K=BUCPI.J+DT*(RCPUR.JK-BCPRR.JK-NCPR.JK)
```

There are two outflows for the base unserviceable compressor inventory. The first, the base compressor repair rate (BCPRR), represents those compressors which will be repaired at base level. This rate is defined by a third-order delay. This delay uses the product of one minus the proportion of compressors to depot and the rate compressors go under repair (RCPUR), and delays it over the compressor repair delay of two weeks. This delay is the standard repair time for compressors at base level.

The other rate coming out of the base unserviceable compressor inventory is the rate compressors declared NRTS (RCPR). It delays the product of the proportion of compressors sent to depot (PCPD) and the rate compressors go under repair (RCPUR) over the NRTS compressor assessment delay of 0.5 weeks. These two rates are set up to indicate they are subject to the number of compressors being put into the repair process. The equations for these two rates are listed here:

```
R        NCPR.KL=DELAY3(PCPD*RCPUR.JK,NCPD)
C        PCPD=0.9
C        NCPD=0.5
R        BCPRR.KL=DELAY3((1-PCPD)*RCPUR.JK,BCPRD)
C        BCPRD=2
```

The level of the depot compressor inventory (DCPI) is determined by the rate compressors declared NRTS (NCPR) minus the depot compressor repair rate (DCPRR). The depot compressor repair rate is derived from a third-order delay of NCPR over the depot compressor repair delay (DCPRD) of six weeks. The equations for DCPI and DCPRR are listed next.

```
L        DCPI.K=DCPI.J+DT*(NCPR.JK-DCPRR.JK)
N        DCPI=0
R        DCPRR.KL=DELAY3(NCPR.JK,DCPRD)
C        DCPRD=6
```

The final level in this sector is the base serviceable compressor inventory (BSCPI). It has a change rate which is equal to the sum of the base compressor repair rate (BCPRR) and the depot compressor repair rate (DCPRR) minus the compressor consumption rate (CPCR). CPCR is the product of the engine repair rate limit (ERRL) and the compressor generation factor. This is presented in this manner to indicate that not all engines are in need of a new compressor when they are brought in. These equations are listed next.

```
L        BSCPI.K=BSCPI.J+DT*(BCPRR.JK+DCPRR.JK-CPCR.JK)
N        BSCPI=BCP
C        BCP=5
R        CPCR.KL=ERRL.JK*CPGF
C        CPGF=0.40
```

This section has discussed the compressor repair process sector. The flow diagram and DYNAMO equations have been presented. The next section will present the quality effects sector.

Quality Effects Sector

Process Description

Quality work, work which returns an engine to a level of performance at or near what it was before the need for maintenance arose, is important. If the work being performed is not of sufficient quality it could lead to decreased operational capability. This would come about because of an increase in the number of unserviceable engines and a rise in the shop work rate. This could, if the condition persists, lead to more unserviceable engines and longer hours for the workers. The cycle is self-reinforcing and will continue to worsen unless some outside force steps in to break the cycle. Taken to the extreme it might even lead to the loss of an aircraft and crew.

There are a number of factors which affect the quality of maintenance being performed. Factors such as training, experience, and morale will be considered in this sector. The premise being that more training and experience and high morale will have a favorable impact. Since the technological factors which affect quality (reliability and ease of repair) are set before purchase, during the design stage, they will not be considered. However, effects from the design stage are evident in the model in the form of repair times and the MTBD.

Causal-Loop Diagram of the Quality Effects Sector

The causal-loop diagram for this sector is shown in Figure 3-13. The diagram shows that as maintenance quality increases, there is a perceived ability to cut down on training. This is especially true in an organization which is undermanned. As the amount of training goes down so does the level of experience, bringing quality down.

Morale will also have an impact on quality. The two main impactors on morale are seen as the perceived availability of outside jobs and personal factors. It is highly probable that others affect quality, however, outside jobs, which gives the worker the incentive to leave the organization is seen as the most important. These outside jobs can be jobs in other fields within the Air Force or jobs in the civilian community. In either case the worker is lost to the system. A personal factors input, something which would account for individual difficulties is also included. Both are seen as having a direct relationship with quality.

The flow diagram developed from this causal-loop diagram is discussed next.

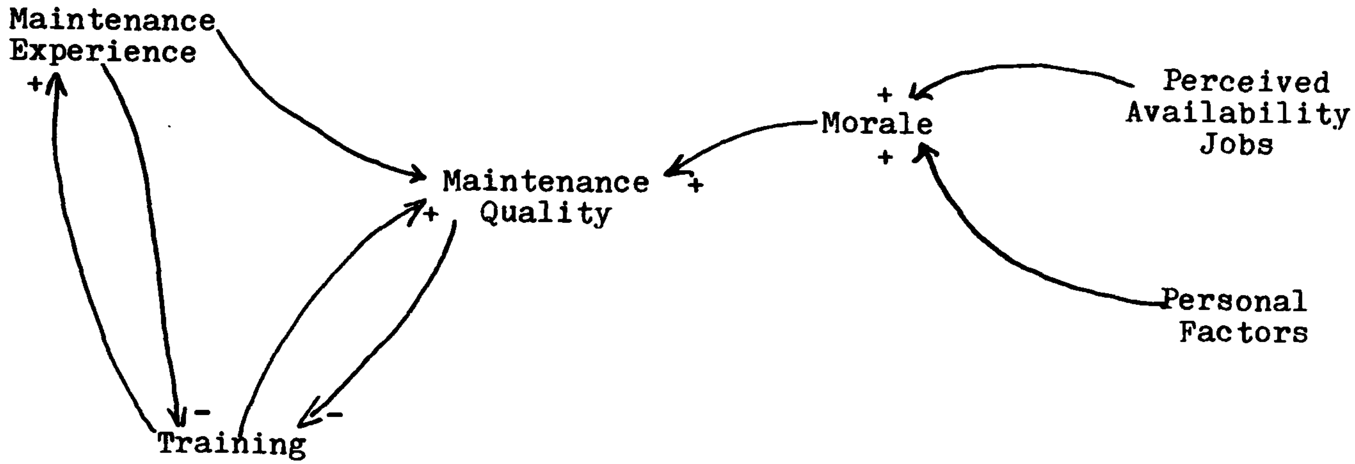


Fig. 3-13. Causal-Loop for the Quality Effects Sector

Flow Diagram for the Quality Effects Sector

The flow diagram for the quality effects sector is shown in Figure 3-14. The quality effects sector is an auxiliary chain which impacts on the rate demand for engines (RDEM) through the mean time between demand (MTBD) variable.

The training factor (TNGF) combines with a random number to yield training (TNG). TNGF is constructed as a sine function. The function will have a very small modulation. In today's Air Force, training and the quality of that training is a closely controlled process. It must be this way because of the importance training has in terms of safety and mission capability. Training is used as an input to the maintenance skill level table (MXSLT). The output of this table is maintenance skill level (MXSL). The shape of MXSLT will be more fully discussed in the section on system equations. MXSL then is used as an input to the maintenance experience table (MEXPT). The shape of this table will also be discussed more fully in the section on system equations. The output of MEXPT is maintenance experience.

The perceived availability of outside jobs is developed as a sine function. It combines with a random number and feeds into a third-order delay. This delay yields morale (MORAL), which is an input to the morale

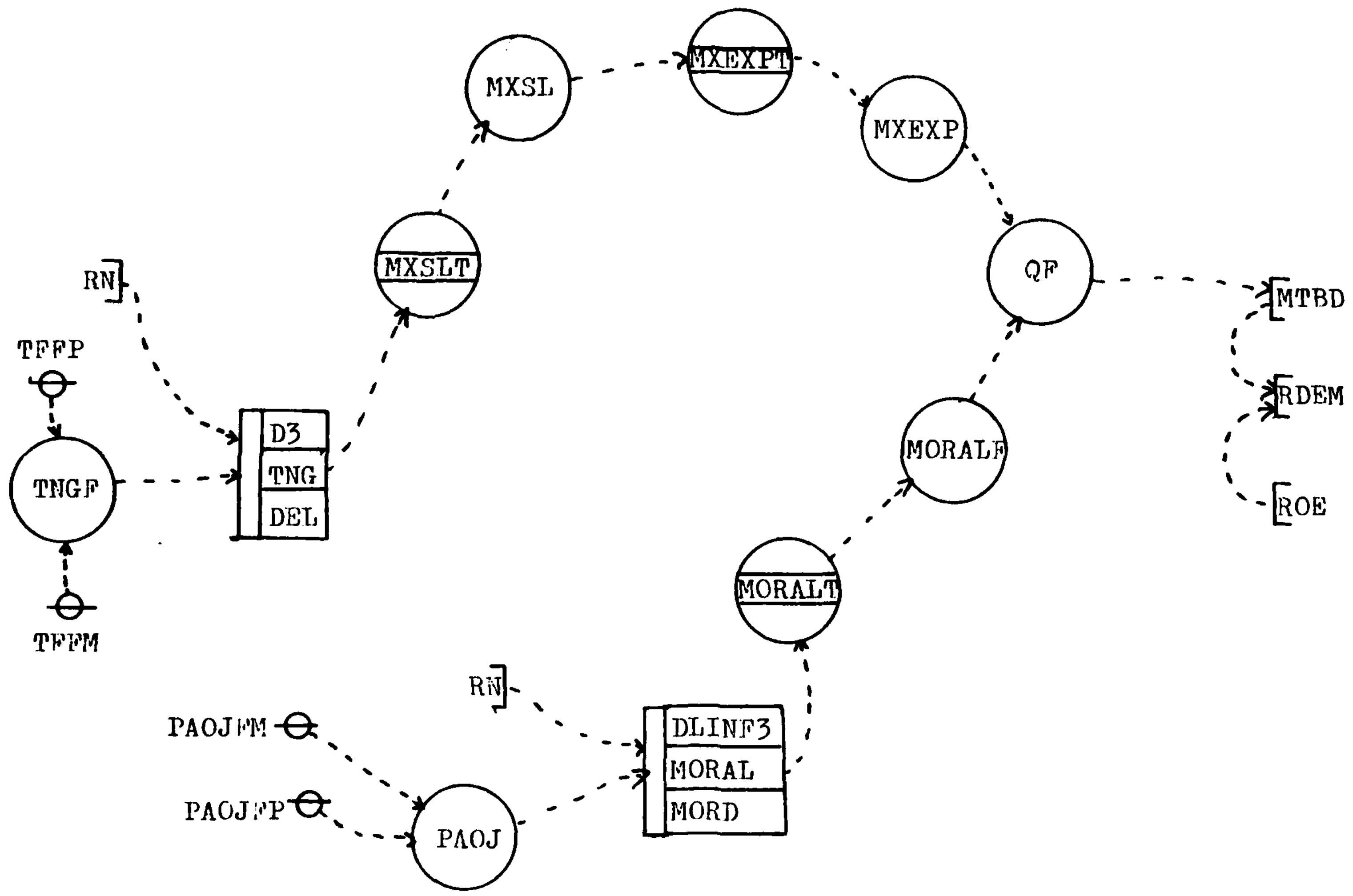


Fig. 3-14. Flow Diagram of the Quality Effects Sector

TABLE 3-4

Variables Appearing in Figure 3-14

MXEMPT	-	MAINTENANCE EXPERIENCE TABLE
MXEXP	-	MAINTENANCE EXPERIENCE
MXSLT	-	MAINTENANCE SKILL LEVEL TABLE
MXSL	-	MAINTENANCE SKILL LEVEL
QF	-	QUALITY FACTOR
RN	-	RANDOM NUMBER
TFFP	-	TRAINING FACTOR FREQUENCY PERIOD
TFFM	-	TRAINING FACTOR FREQUENCY MODULATION
TNGF	-	TRAINING FACTOR
TNG	-	TRAINING
DEL	-	DELAY FOR TRAINING (WKS)
PAOJFP	-	PERCEIVED AVAILABILITY OF OUTSIDE JOBS FREQUENCY PERIOD
PAOJFM	-	PERCEIVED AVAILABILITY OF OUTSIDE JOBS FREQUENCY MODULATION
PAOJ	-	PERCEIVED AVAILABILITY OF OUTSIDE JOBS
MORAL	-	MORALE
MORD	-	MORALE DELAY (WKS)
MORALT	-	MORALE TABLE
MORALF	-	MORALE FACTOR
MTBD	-	MEAN TIME BETWEEN DEMAND
RDEM	-	RATE OF DEMAND
ROE	-	RATE OF EFFORT

table to give the morale factor. The shape of the morale table will be discussed more fully in the section on system equations.

The morale factor and maintenance experience are combined to form the quality factor (QF). The reasoning behind this formulation is that happy workers with a high level of experience will do better work. This is used in the mean time between demand. A high level of quality in the repair process should cause the mean time between demand to increase, all other things being equal.

From the flow diagrams just described DYNAMO equations were developed. These equations are discussed next.

DYNAMO Equations for the Quality Effects Sector

The training factor (TNGF) was developed as a sine function. It has a modulation of .25 and a period of 78 weeks. The relatively small modulation was chosen to indicate the importance of training in the Air Force. Every attempt is made to keep the training which personnel receive at a high level of quality. The period of 78 weeks was chosen as an estimate of the amount of time needed to perceive and react to changes in the quality of training personnel are receiving. A random number, taken from the NOISE function, was added to the training factor to represent individual differences.

The training factor is put through a third-order delay of eight weeks. Eight weeks was used as a rough estimate of the amount of time necessary to complete a training course. The output of this delay is training (TNG).

Training is used as an input to the maintenance skill level table (MXSLT). The table, shown in Figure 3-15, is intended to show the accumulation of skill, the ability to perform a given task. Since any inherent skill is worthless without the proper training, the table has a minimum value of zero. The value of the table increases rapidly as training increases. This increase in skill slows after 0.8 and a maximum value of 0.98 is given to maintenance skill (MXSL). This upper limit is set to indicate the impossibility of attaining perfection.

Maintenance skill level is used as an input to the maintenance experience table (MXEXPT). This table, shown in Figure 3-16, is developed along the same lines as MXSLT. The major difference being a slower increase in the value for maintenance experience (MXEXP), the output of the table. This is an attempt to show that job experience takes longer to develop than job skill. The maximum value of this table is also 0.98. This upper limit is set to illustrate the inability of individuals to experience every facet of their jobs. The upper limit of this table and MXSLT could have been set an any value,

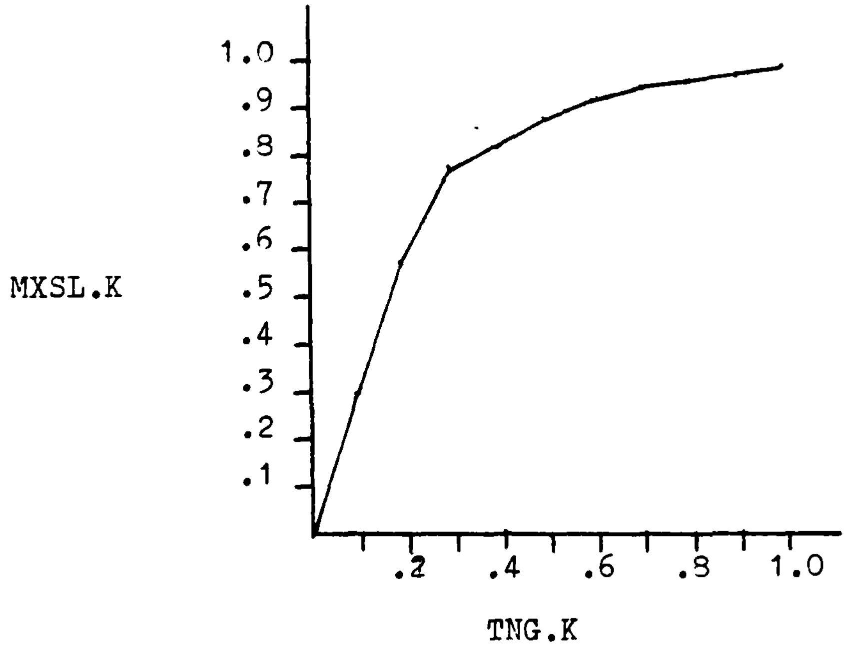


Fig 3-15 The Maintenance Skill Level Table

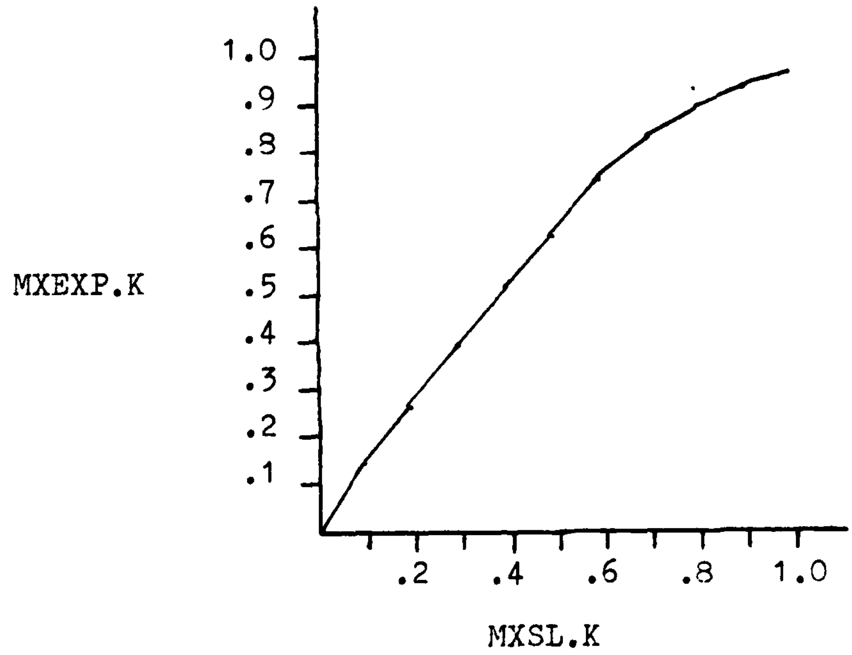


Fig. 3-16 The Maintenance Experience Table

however, an upper limit in this range seems reasonable. The equations used to derive MXEXP are listed below:

```
A         MXEXP.K=TABLE(MXEXPT,MXSL.K,0,1,.1)
T         MXEXPT=0/.14/.27/.40/.51/.62/.74/.81/.94/.98
A         MXSL.K=TABLE(MXSLT,TNG.K,0,1,.1)
T         MXSLT=0/.3/.58/.78/.82/.88/.91/.94/.96/.97/.98
A         TNG.K=DELAY3(RN.K+TNGF.K,DEL)
A         TNGF.K=.5+TFFM*SIN(6.28*TIME.K/TFFP)
C         DEL=8
C         TFFP=78
C         TFFM=.25
```

The auxiliary chain which develops the morale factor is discussed next. The purpose of this chain is to show the effects of the availability of outside jobs (PAOJ) on the worker. The term morale is used to signify the way an individual feels about his job, and additionally, whether he would be willing to leave it for some other job. In order to account for extraneous inputs which might affect the worker, a random number from the NOISE function is added to PAOJ.

The perceived availability of outside jobs (PAOJ) is set up as a sine function. It has a modulation of .75 and a period of forty weeks. The modulation was set at .75 to show the ebb and flow of the job market. The period was set at forty weeks to show the amount of time it takes jobs to appear, be filled and appear again.

PAOJ is used as an input to a third-order information delay. The variable is delayed over the morale delay (MORD) of 2.5 weeks. This is the amount of time it should take a person to notice there are other jobs available and start an earnest search. The output of this delay is morale (MORAL).

Morale is used as an input to the morale table (MORALT). This table is a combination of two factors. The first is the individuals perception of available outside jobs. The second is his willingness to leave his present job. As Figure 3-17 shows, there is no change in the morale factor (MORALF) until morale gets to

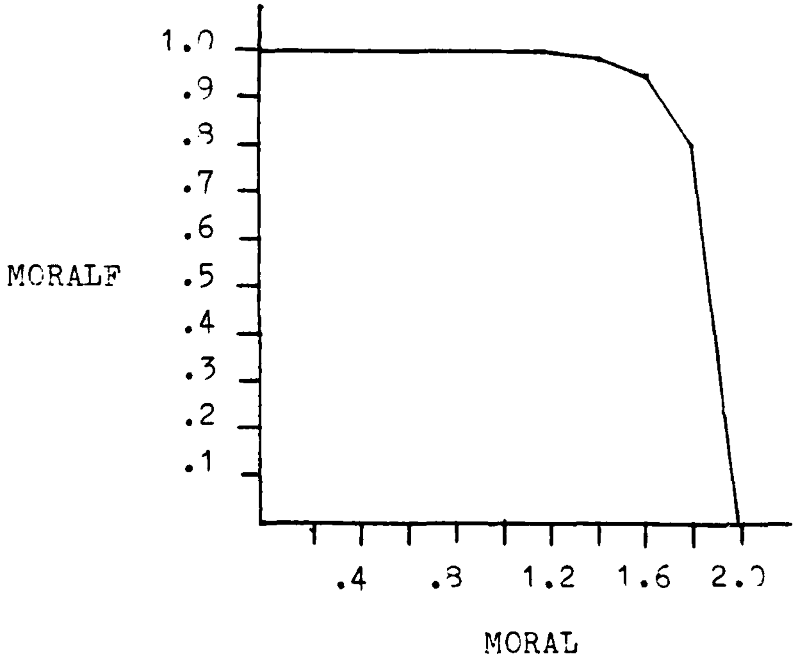


Fig. 3-17 The Morale Factor Table

AD-A122 829 A SYSTEM DYNAMICS POLICY ANALYSIS MODEL OF THE AIR FORCE ENGINE MANAGEMENT SYSTEM(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST.. 2/3

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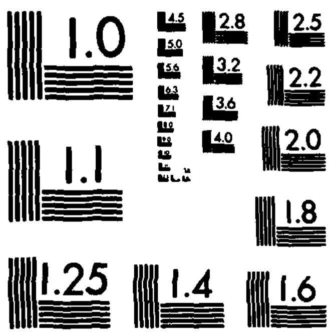


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

approximately 1.5. It then begins a rapid decrease. This is intended to show that people will tolerate a great deal, however, once a limit is reached, morale will deteriorate rapidly. The equations used to develop the morale factor are shown below:

```
A          MORALF.K=TABLE(MORALT,MORAL.K,0,2,.2)
A          MORAL.K=DLINF3(PAOJ.K+RN.K,MORD)
C          MORD=2.5
A          PAOJ.K=1+PAOJFM(SIN(6.28*TIME.K)/PAOJFP)
C          PAOJFM=.75
C          PAOJFP=40
```

The value of the quality factor (QF) is obtained by multiplying maintenance experience by the morale factor. This is used to show that a happy, experienced worker will do a better job than one who is unhappy, inexperienced, or both.

```
A          QF.K=MXEXP.K*MORALF.K
```

This section has discussed the development of a quality effect sector. Flow diagrams and DYNAMO equations were presented and discussed. The next section will discuss the routine requisition process sector.

Routine Requisition Process Sector

Process Description

The goal of this sector is to insure that an adequate number of engines will be available at base level. To achieve this a link is formed between the base and depot inventories. The purpose of this sector is to compensate the base for the loss of engines due to NRTS actions. This is done by calculating the pipeline inventory needed to support base level demands for serviceable engines. Knowledge of the pipeline quantities allows the calculation of a safety level quantity. If there are no major long-term changes, a requisition will be created only when an engine is declared NRTS.

The tracking of requisitions is required to keep from double ordering against a single requirement and to monitor system performance. Once transmitted to the depot a requisition will be counted as a backorder on the depots' serviceable engine inventory until it is satisfied by a shipment from the depot. From this process description a causal-loop diagram can be drawn.

Causal-Loop Diagram of the Routine Requisition Process

Figure 3-18 is a causal-loop diagram of the base routine requisition process. As the engine demand rate increases a like increase is seen in the perceived demand rate and the daily demand rate. The engine demand rate also causes an increase in unserviceable engines. Both unserviceable engines and the perceived demand rate have a direct impact on the engine repair rate.

The engine repair rate has an inverse relationship with the routine shipments from the depot. As the

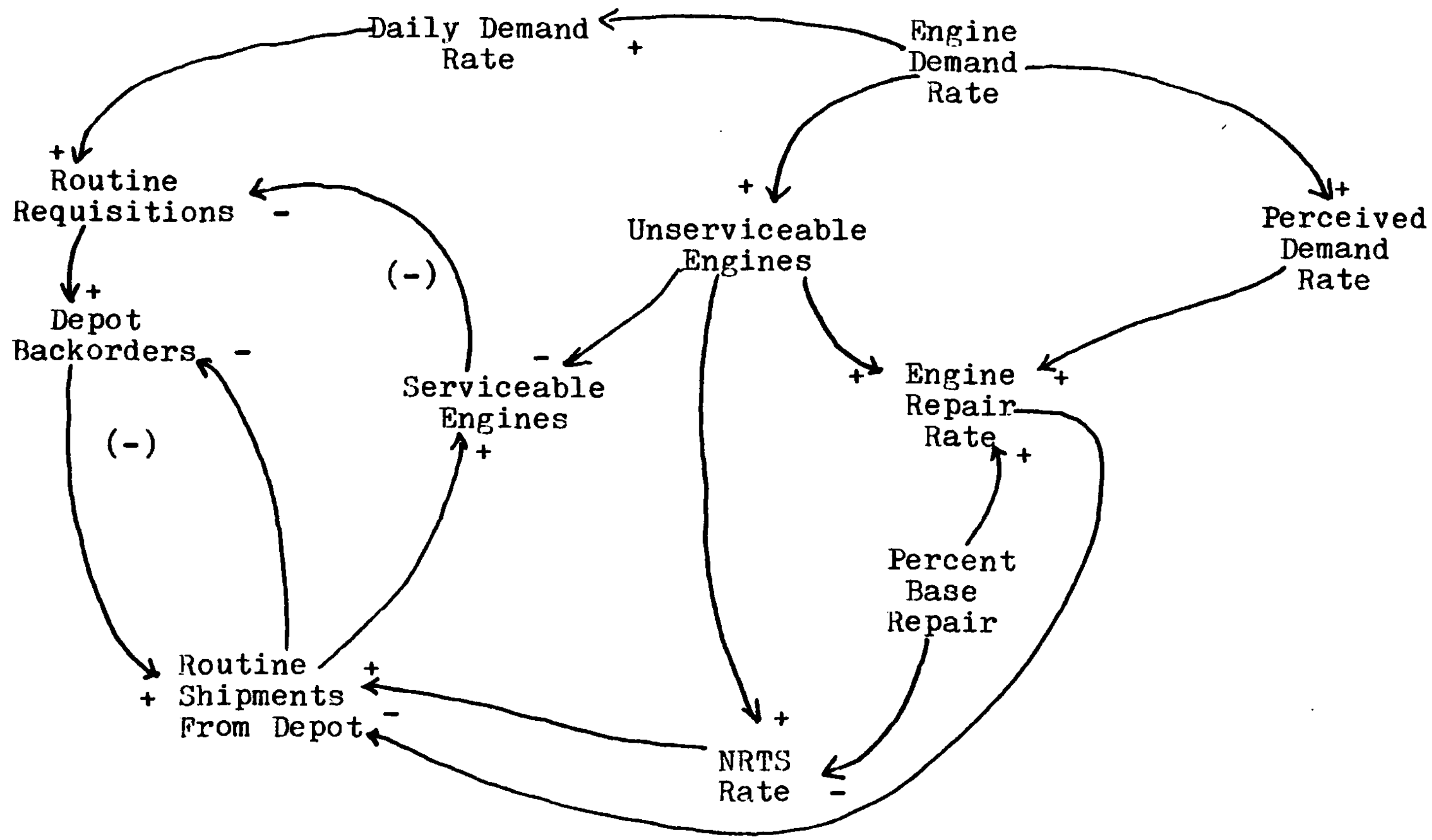


Fig. 3-18. Causal-Loop Diagram of the Base-Level Requisition Process Sector

engine repair rate goes up the shipments from depot will go down.

The engine demand rate has a direct relationship with the daily demand rate. These two variables, while similar, are not the same. The daily demand rate is a 180 day moving average of the demand for engines. An increase in the daily demand rate will cause an increase in routine requisitions. This increase in routine requisitions causes a like increase in the number of depot backorders. As backorders increase the routine shipments from the depot will also increase.

An increase in routine shipments from the depot will cause an increase in the number of serviceable engines and a decrease in depot backorders. As the serviceable engines increase the routine requisition will decrease.

An increase in the engine demand rate will also increase the number of unserviceable engines. This increase in the unserviceables causes an increase in both the NRTS rate and the engine repair rate.

As shown in the diagram the major influence in this sector is the engine demand rate. This demand rate will impact on routine shipments through the engine repair rate and the daily demand rate.

From this causal-loop diagram and the process description a flow diagram of the requisition process can be developed. This flow diagram will be discussed next.

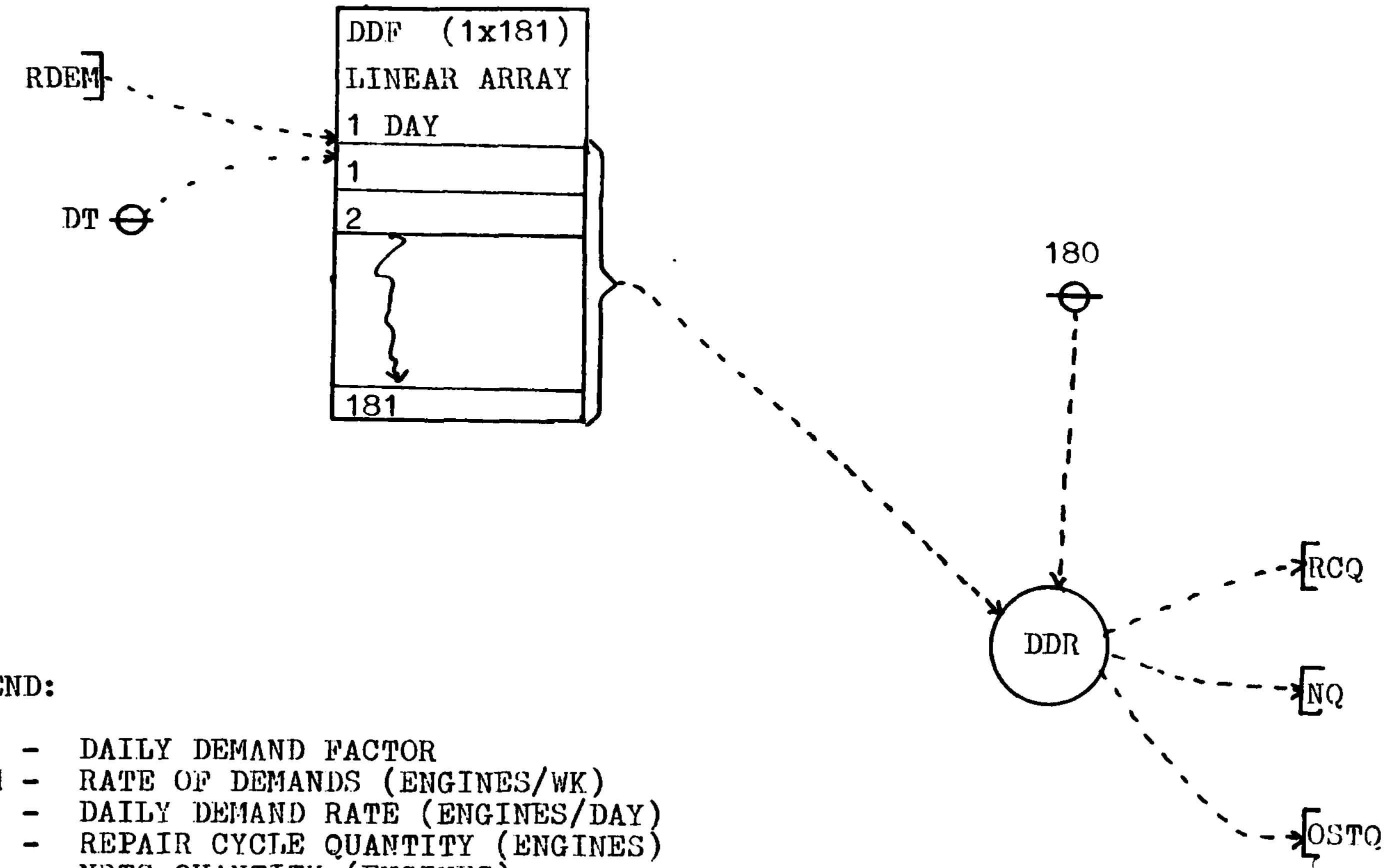
Flow Diagram of the Routine Requisition Process

The flow diagrams for this sector are shown in Figures 3-19, 3-20, and 3-21. The diagrams were separated for ease of reading.

Figure 3-19 is the flow diagram for the daily demand computation. The rate of demand (RDEM) combines with the computation interval to yield the daily demand factor (DDF). DDF, a linear array, is used to obtain the repair cycle quantity (RCQ), NRTS quantity (NQ), and the order and ship time quantity (OSTQ).

A linear array is used to obtain these quantities in terms of a 180 day moving average. This format was used because the Air Force uses a 180 day moving average to compute its required inventory levels.

Figure 3-20 is the flow diagram for the repair rate computation. The rate unserviceables return to service (RURS) combines with the computation interval (DT) to yield the reparable this station factor (RTSF), a linear array with the same dimensions as DDF. At the same time, the rate engines are declared NRTS (RNRTS), the diversion to depot rate (DTDR), and the computation interval (DT), combine to give the not reparable this station factor (NRTSF), also a linear array with the same dimensions as DDF. This structure is used to obtain a 180 day moving average of the repair process. RTSF and NRTSF



LEGEND:

DDF - DAILY DEMAND FACTOR
RDEM - RATE OF DEMANDS (ENGINES/WK)
DDR - DAILY DEMAND RATE (ENGINES/DAY)
RCQ - REPAIR CYCLE QUANTITY (ENGINES)
NQ - NRTS QUANTITY (ENGINES)
OSTQ - ORDER AND SHIP TIME QUANTITY (ENGINES)

Fig. 3-19. Flow Diagram for the Daily Demand Rate

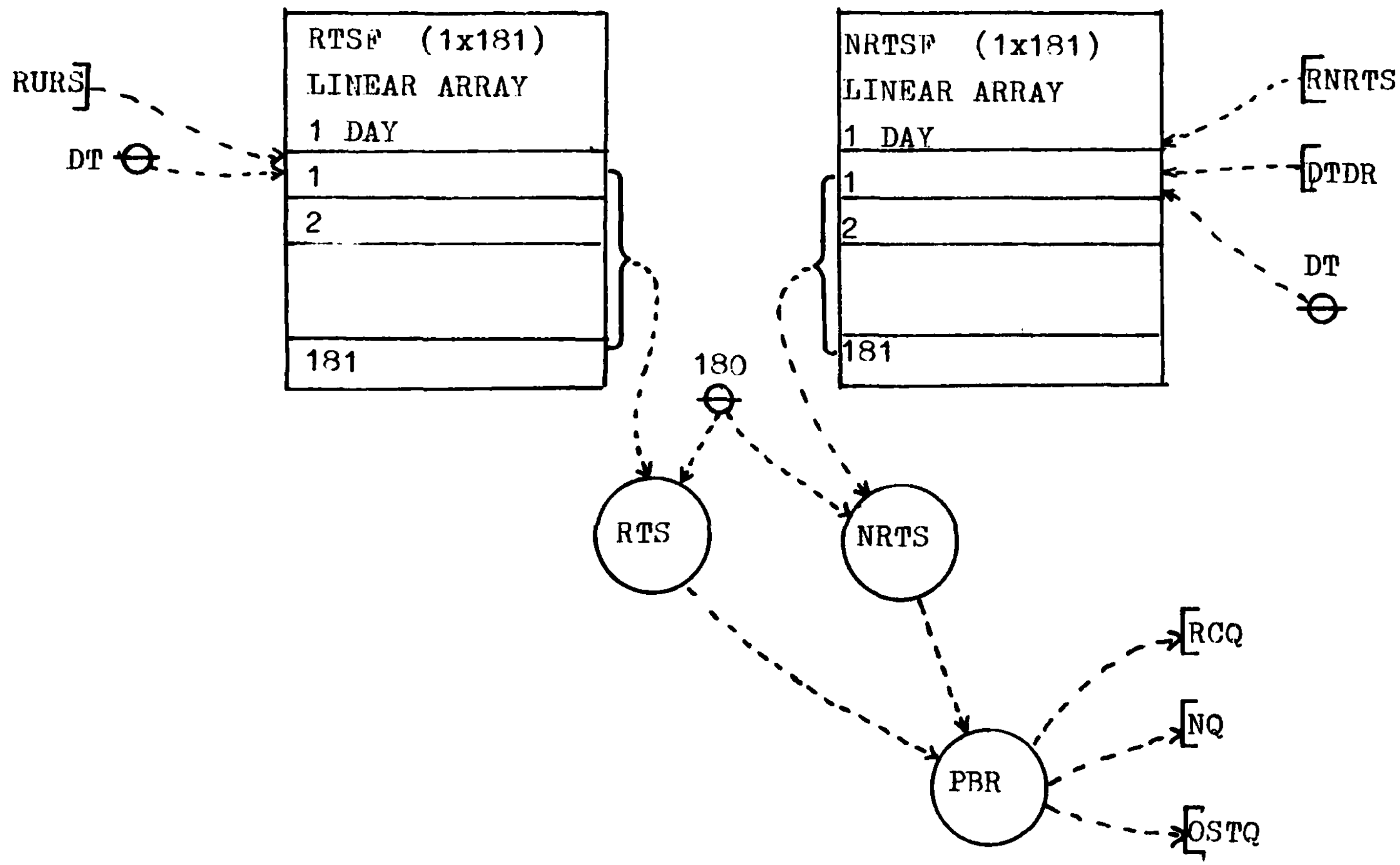


Fig. 3-20. Flow Diagram for the Percentage Base Repair

TABLE 3-5

Variables Appearing in Figure 3-20

RTSF	-	REPARABLE THIS STATION FACTOR
RURS	-	RATE AT WHICH UNSERVICEABLES RETURN TO SERVICE (ENGINES/WK)
RTS	-	REPARABLE THIS STATION (ENGINES/DAY)
NRTSF	-	NOT REPARABLE THIS STATION FACTOR
RNRTS	-	RATE ENGINES DECLARED NRTS (ENGINES/WK)
DTDR	-	DIVERSION TO DEPOT RATE (ENGINES/WK)
NRTS	-	NOT REPARABLE THIS STATION (ENGINES/DAY)
PBR	-	PERCENTAGE BASE REPAIR
RCQ	-	REPAIR CYCLE QUANTITY (ENGINES)
NQ	-	NRTS QUANTITY (ENGINES)
OSTQ	-	ORDER AND SHIP TIME QUANTITY (ENGINES)

combine with 180 to yield the variables RTS and NRTS which combine to yield the percentage base repair (PBR). PBR is used as an input to repair cycle quantity, NRTS quantity, and order and ship time quantity.

Figure 3-21 is the flow diagram for repair cycle quantities, demand computation, and depot backorders. The daily demand (DDR) and the percentage base repair (PBR) combine with the repair cycle time (RCT) to yield the repair cycle quantity (RCQ). DDR and PBR combine with the order and ship time (OST) to yield the order and ship time quantity (OSTQ). RCQ, NQ, and OSTQ combine to give the safety level quantity (SLQ). These quantities are those which are required to fill the repair and transportation pipelines and ensure a buffer inventory is maintained to protect the system from surges in demand at base level.

The base serviceable stock (BSS) and the safety level quantity (SLQ) combine to yield the trial requisition quantity (TRQ). This quantity is used to represent the decision structure used to place an order with the depot. It is combined with the actual requisitions placed with depot (ARQP) to yield the actual requisitions quantity (ARQ). ARQ when combined with the computation interval (DT) will give the instantaneous order rate (IOR).

The instantaneous order rate determines the actual

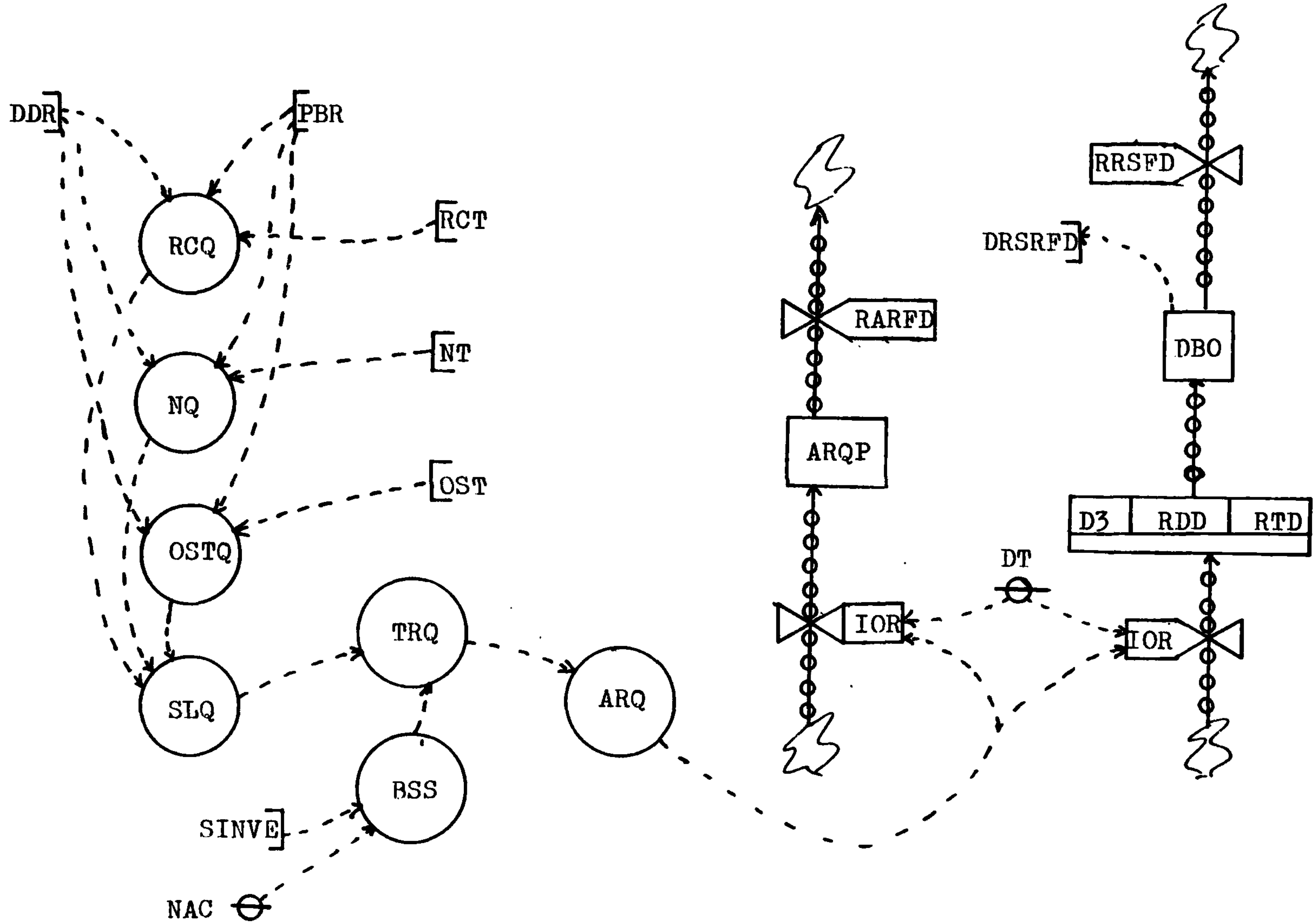


Fig. 3-21. Flow Diagram for Repair Cycle Quantities, Requisitions and Depot Backorders

TABLE 3-6

Variables Appearing in Figure 3-21

RCQ	-	REPAIR CYCLE QUANTITY (ENGINES)
DDR	-	DAILY DEMAND RATE (ENGINES/DAY)
PBR	-	PERCENTAGE BASE REPAIR
RCT	-	REPAIR CYCLE TIME (DAYS)
NQ	-	NRTS QUANTITY (ENGINES)
NT	-	NRTS ASSESSMENT TIME (DAYS)
OSTQ	-	ORDER AND SHIP TIME QUANTITY (ENGINES)
OST	-	ORDER AND SHIP TIME (DAYS)
SLQ	-	SAFETY LEVEL QUANTITY (ENGINES)
BSS	-	BASE SERVICEABLE STOCK (ENGINES)
SINVE	-	SERVICEABLE INVENTORY OF ENGINES (ENGINES)
NAC	-	NUMBER OF AIRCRAFT (UNITS)
TRQ	-	TRIAL REQUISITION QUANTITY (ENGINES)
ARQP	-	ACTUAL REQUISITIONS PLACED WITH DEPOT (ORDERS)
RARFD	-	RATE OF ARRIVAL OF ROUTINE SHIPMENTS FROM DEPOT (ENGINES/WK)
ARQ	-	ACTUAL REQUISITION QUANTITY (ENGINES)
IOR	-	INSTANTANEOUS ORDER RATE (ENGINES ORDERS/WK)
RDD	-	REQUISITION DELAY TO DEPOT (ORDERS/WK)
RTD	-	REQUISITION TRANSMISSION DELAY (WKS)
DBO	-	DEPOT BACKORDERS (ORDERS)
RRSFD	-	RATE OF ROUTINE SHIPMENTS FROM DEPOT (ENGINES/WK)
DRSRFD	-	DESIRED SHIPMENT RATE FROM DEPOT

requisitions placed with the depot and, in turn, the rate of arrival of shipments from the depot (RARFD). It also determines the requisition delay to depot (RDD) via a third-order delay which yields the level of depot backorders (DBO) and ultimately the rate of routine shipments from the depot (RRSFD) as well as the desired rate of routine shipments from the depot (DRSRFD). This entire structure is an attempt to capture the decision process used by managers to decide whether an engine will be ordered to satisfy a requirement.

From the flow diagram just described DYNAMO equations are developed. These equations are developed next.

DYNAMO Equations for the Routine Requisition Process

The DYNAMO equations for the daily demand rate are as follows:

```
FOR      I=1,181
L        DDF.K(1)=DDF.J(1)+DT*RDEM.JK
N        DDF(I)=0.02
A        DDR.K=SUMV(DDF.K,2,181)/180
S        LDD.K=SHIFTL(DDF.K,.143)
```

The FOR statement is a fortran insert used to alert DYNAMO of the presence of an array. In this case, the arrays will be linear and 181 blocks long. Each block corresponds to one day.

The daily demand factor is a level with a change rate equal to the rate of demand for engines. The daily demand factor is then summed over its range of values and then divided by 180 to yield the daily demand rate. With each additional day the SHIFTL function discards the 181st day and adds the new value to the first spot. This structure is used to represent the computation of a 180 day moving average for the demand rate.

The base repair rate computation equations are as follows:

```
L         RTSF.K(1)=RTSF.J(1)+DT*RURS.JK
N         RTSF(I)=0.8
A         RTS.K=SUMV(RTSF.K,2,181)/180
S         LRTS.K=SHIFTL(RTSF.K,.143
L         NRTSF.K(1)=NRTSF.K(1)+DT(RNRTS.JK+DTDR.JK)
N         NRTSF(I)=0.2
A         NRTS.K=SUMV(NRTSF.K,2,181)/180
S         LNRTS.K=SHIFTL(NRTSF.K,.143)
A         PBR.K=RTS.K/(RTS.K+NRTS.K)
```

These equations are used to capture the moving average of the reparable and not reparable this station factor. This is computed in the same fashion as described for the daily demand rate. Again, 180 days is used because it corresponds to the length of time over which the daily demand rate is averaged.

The repair cycle quantities are derived in the following equations:

```
A         RCQ.K=(DDR.K*PBR.K*RCT)
C         RCT=14              - IN DAYS
A         NQ.K=DDR.K*(1-PBR.K)*NT
C         NT=8                - IN DAYS
A         OSTQ.K=DDR.K*(1-PBR.K)*OST
C         OST=6               - IN DAYS
A         SLQ.K=SQRT(3*(RCQ.K+NCQ.K+OSTQ.K))*CFACT
C         CFACT=2.0
```

The repair cycle quantity (RCQ) is equal to the daily demand rate times the percentage base repair (PBR) times the repair cycle time (RCT). This equation is used to obtain the number of engines in the base repair cycle. This quantity is used in deriving the safety level quantity.

The NRTS quantity (NQ) is equal to the daily demand rate times one minus the percentage base repair times the NRTS assessment time (NT). The equation is used to determine the quantity of engines being sent to the depot for repair. This, also, will be used to derive the safety level quantity.

The order and ship time quantity (OSTQ) is obtained by multiplying the daily demand rate by one minus the percentage base repair multiplied by the order and shipment time (OST). This is the quantity which will be in the transportation pipeline, given a certain daily demand. It is also used in the determination of the safety level quantity.

The safety level is a function of the repair cycle quantity, NRTS quantity, and order and shipment quantity. These quantities give the number of engines which must be on hand to provide a margin of safety against surges in the use rate of engines.

The base serviceable stock (BSS) is obtained by taking the maximum of zero and the difference between the serviceable inventory of engines and the number of aircraft multiplied by the engine correction factor (ECF). This formulation is used to derive the number of serviceable spares on the base. A MAX function is used because a negative quantity of spares would not be useful for this model. The equation used to derive base serviceable stock is listed below.

```
A        BSS.K=MAX(0,(SINVE.K-NAC*ECF))
```

The trial requisition quantity is derived in the following equation:

```
A        TRQ.K=MAX(0,(SLQ.K-BSS.K))
```

This formulation is used to avoid ordering a negative quantity, which would be meaningless.

The level, actual requisitions placed with the depot (ARQP), is determined by the following equations:

```
L        ARQP.K=ARQP.J+DT*(IOR.JK-RARFD.JK)
N        ARQP=0
```

This is the number of requisitions which would be placed based on the order rate and the arrival of shipments from the depot. This quantity, and the trial requisition quantity (TRQ), is used to derive the actual requisition quantity. This is an attempt to capture the decision structure used when placing orders. Managers will make a decision on what to order based on the experience with the arrival rate of shipments and the status of their inventory. The equation for actual requisition quantity is shown below.

```
A          ARQ.K=MAX(0,(TRQ.K-ARQP.K))
```

This quantity is used in determining the instantaneous order rate. This is used because managers will base the orders they make upon their knowledge of the orders which were made previously. The equation for IOR is listed below.

```
R          IOR.KL=ARQ.K/DT
```

For the purpose of this model an order placed with the depot is counted as a backorder until it is satisfied. The equations for this string are shown next.

```
L          DBO.K=DBO.J+DT*(RDD.JK-RRSFD.JK)
N          DBO=0
R          RDD.KL=DELAY3(IOR.KL,RTD)
C          RTD=.1
```

This structure is used to capture the number of backorders which will be at the depot. The requisition delay to depot (RDD) is a third-order delay of the instantaneous order rate over the requisition transmission delay (RTD) of 0.1 week. This time was used because it is the length of time needed to place an order with the depot.

This section has presented the routine requisition process sector. The flow diagrams and system equations were presented and discussed. The next section will present the depot repair sector.

Depot Repair Process Sector

Process Description

The depot repair sector consists of the following two sub-processes:

1. The movement of unserviceable engines from base to depot for repair and;

2. The repair of unserviceable engines, returning them to the depot inventory of serviceable engines.

These two processes may experience delays, if the item manager determines that the depot serviceable stock is low he may shorten the time an engine will wait before it goes under repair. Conversely, should the stock of serviceable engines be high the engine may experience a delay before going into the repair cycle.

Causal-Loop Diagram of the Depot Repair Process

Figure 3-22 is a causal-loop diagram of the depot repair process. An increase in the base unserviceable

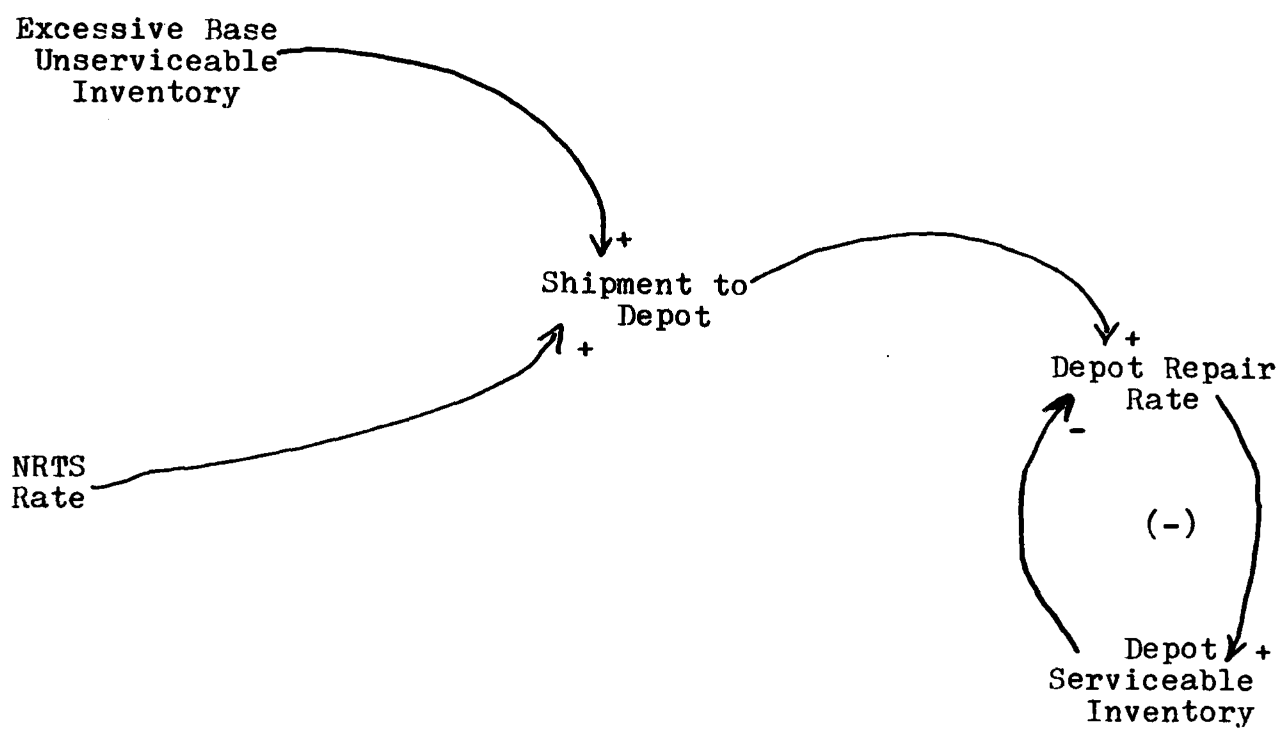


Fig. 3-22. Causal-Loop Diagram for the Depot Repair Process Sector

engine inventory will increase the shipments of unserviceable engines to the depot, as will an increase in the NRTS rate. As shipments to the depot increase, the depot repair rate will be increased. This increase in the depot repair rate will cause an increase in the depot serviceable inventory, which decreases the depot repair rate.

From the causal-loop diagram just described, a flow diagram can be drawn. This flow diagram will be discussed next.

Flow Diagram of the Depot Repair Process

The flow diagram for this sector is shown in Figure 3-23. The unserviceable inventory of engines (USINVE) and the maximum base backlog (MBBLOG) combine to give the excess base maintenance backlog (EBBLOG). EBBLOG is then combined with the computation interval (DT) to yield the trial diversion to depot rate (TDTDR).

The depot maximum throughput (DMAXTP) and the rate engines are declared NRTS (RNRTS) are combined to form the diversion to depot rate limit (DTDRL). This limit and the trial diversion to depot rate (TDTDR) are then combined to yield the diversion to depot rate. This structure is used to show that the diversion to depot rate will be a function of the workload at base level.

The NRTS rate and the diversion to depot rate

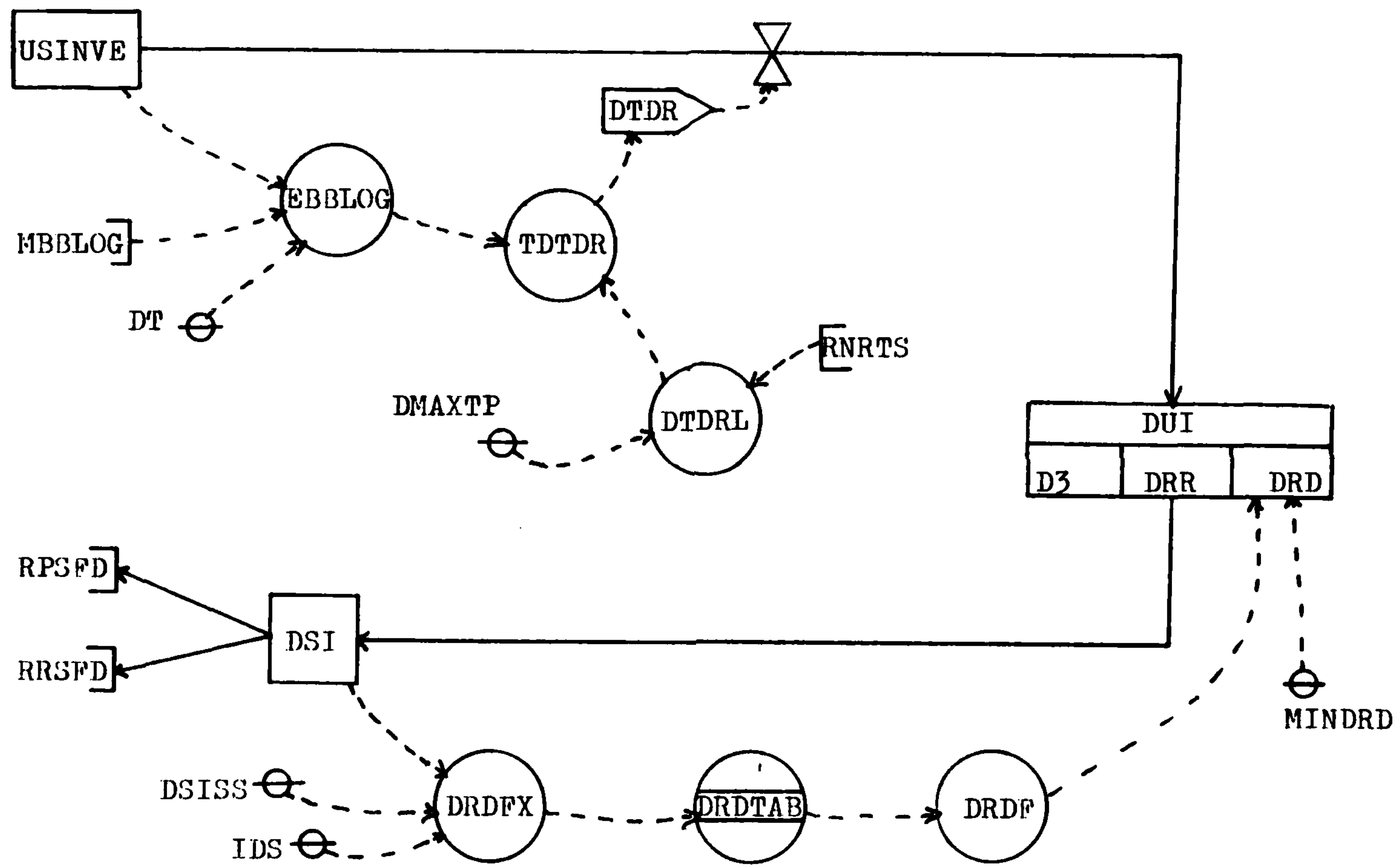


Fig. 3-23. Flow Diagram for the Depot Repair Process

TABLE 3-7

Variables Appearing in Figure 3-23

EBBLOG	-	EXCESS BASE MAINTENANCE BACKLOG (ENGINES)
USINVE	-	UNSERVICEABLE ENGINE INVENTORY (ENGINES)
MBBLOG	-	MAXIMUM BASE MAINTENANCE BACKLOG (ENGINES)
TDTDR	-	TRIAL DIVERSION TO DEPOT RATE (ENGINES/WKS)
DTDRL	-	DIVERSION TO DEPOT RATE LIMIT (ENGINES/WK)
DMAXTP	-	DEPOT MAXIMUM REPAIR THROUGHPUT (ENGINES/WK)
RNRTS	-	RATE ENGINES DECLARED NRTS (ENGINES/WK)
DTDR	-	DIVERSION TO DEPOT RATE (ENGINES/WK)
DUI	-	DEPOT UNSERVICEABLE INVENTORY (ENGINES)
DRR	-	DEPOT REPAIR RATE (ENGINES/WK)
DRDFX	-	DEPOT REPAIR DELAY FACTOR INDEX
DRDF	-	DEPOT REPAIR DELAY FACTOR
DRDTAB	-	DEPOT REPAIR DELAY TABLE
IDS	-	INITIAL DEPOT STOCK (ENGINES)
DSISS	-	DEPOT SERVICEABLE INVENTORY SAFETY STOCK (ENGINES)
DRD	-	DEPOT REPAIR DELAY (WKS)
DSI	-	DEPOT SERVICEABLE INVENTORY (ENGINES)
RRSFD	-	RATE OF ROUTINE SHIPMENTS FROM DEPOT (ENGINES/WK)
RPSFD	-	RATE OF PRIORITY SHIPMENTS FROM DEPOT (ENGINES/WK)

are the inputs to the depot unserviceable inventory (DUI) level. The depot repair rate (DRR) is the outflow of the depot unserviceable inventory. This structure shows engines waiting in an unserviceable inventory prior to being put into repair. This repair rate is seen as a third-order delay. It is a function of the depot repair delay factor (DRDF) and the minimum depot repair delay.

The depot serviceable inventory (DSI) is the result of the depot repair rate acting upon the depot unserviceable inventory (DUI). The depot repair delay factor index is derived from the depot serviceable inventory and the depot serviceable inventory safety stock (DSISS). The depot repair delay factor index then combines with the depot repair delay table (DRDTAB) to yield the depot repair delay factor. This structure is used to capture the decision process involved in deciding how soon an engine will be started in maintenance.

From the depot serviceable inventory flows two separate rates. They are the rate of priority shipments from the depot (RPSFD), and the rate of routine shipments from the depot (RRSFD). These will be discussed in the section on the depot resupply sector.

From the flow diagram just described, DYNAMO equations are developed. These equations are presented next.

DYNAMO Equations for the Depot Repair Process

The excess base maintenance backlog is derived from a maximum function. The function returns zero or the difference between the unserviceable inventory of engines and the maximum base maintenance backlog. EBBLOG is then divided by the computation interval (DT) to yield the trial diversion to depot rate. The diversion to depot rate limit is the difference between the depot maximum throughput (DMAXTP) and the rate engines are declared NRTS. The diversion to depot rate (DTDR) is obtained from a FIFGE macro. This macro returns either DTDRL or the TDTDR, as appropriate. This formulation is used to capture the decision structure involved in sending an engine to the depot. These equations are listed below.

```
A          EBBLOG.K=MAX(USINVE.K-MBBLOG,0)
C          MBBLOG=2
A          TDTDR.K=EBBLOG.K/DT
A          DTDRL.K=DMAXTP-RNRTS.JK
C          DMAXTP=.4
R          DTDR.KL=FIFGE(DTDRL.K,TDTDR.K,TDTDR.K,DTDRL.K
C          DMAXTP=.4
R          DTDR.KL=FIFGE(DTDRL.K,TDTDR.K,TDTDR.K,DTDRL.K)
```

The depot unserviceable inventory (DUI) level equation has a change function of the rate engines are declared NRTS and the diversion to depot rate (DTDR) minus the depot repair rate. This is an attempt to show that control of the depot unserviceable inventory is dependent upon the depot repair rate staying even, or ahead of the rate engines are coming into the depot, RNRTS and DTDR. The equations for DUI are listed next.

L DUI.K=DUI.J+DT*(RNRTS.JK+DTDR.JK-DRR.JK)

N DUI=0

The depot repair rate (DRR) is a third-order delay of the sum of the rate engines are declared NRTS and the diversion to depot rate. The sum is delayed over the depot repair delay. This is used to show that the depot repair rate will be based upon the number of engines coming into the depot for repair.

The depot repair delay is obtained from an auxiliary chain. The chain starts with the depot repair delay factor index. This is obtained by dividing the depot serviceable inventory (DSI) by the depot serviceable inventory safety stock (DSISS). The depot repair delay factor index is used as an input to the depot repair delay table (DRDTAB) to yield the depot repair delay factor (DRDF). When the depot repair delay factor is multiplied by the minimum depot repair delay (MINDRD) of 3.5 weeks, the depot repair delay is obtained. This formulation is used in an attempt to capture the decision process involved in putting engines through the repair process. As noted earlier, the engine manager will vary the rate engines go through repair dependent upon the status of the depot serviceable inventory. The equations which are used to do this are shown below.

```
R     DRR.KL=DELAY3((RNRTS.JK+DTDR.JK),DRD.K)
A     DRDFX.K=DSI.K/DSISS
A     DRDF.K=TABHL(DRDTAB,DRDFX.K,1.1,IDS/DSISS,
          (IDS(DSISS)-1.1)
T     DRDTAB=1/2.75
C     IDS=10
C     DSISS=2
A     DRD.K=DRDF.K*MINDRD
C     MINDRD=3.5
```

The final equation to be discussed in this section is the level, depot serviceable inventory (DSI). This equation has a change rate of the depot repair rate minus the rate of shipments from the depot, both routine (RRSFD) and priority (RPSFD). The equation for DSI is listed below:

```
L     DSI.K=DSI.J+DT*(DRR.JK-RRSFD.JK-RPSFD.JK)
N     DSI=IDS
```

This section has discussed the depot repair process. The flow diagram and DYNAMO equations were presented and discussed. The next section will discuss the depot resupply sector.

Depot Resupply Process Sector

Process Description

This sector deals with the link between depot serviceable and base serviceable inventories. The resupply of base inventories is performed in two ways. The first, is routine shipments that arise from day-to-day operations. The second, is priority shipments. These priority shipments are used to satisfy mission capable (MICAP) requirements. The need for these shipments arises when the routine resupply system does not keep the base serviceable inventory at a level which will support the flying hour program.

From this process description a causal-loop diagram can be drawn. This diagram will be discussed next.

Causal-Loop Diagram of the Depot Resupply Process

Figure 3-24 is a causal-loop diagram of the depot resupply process sector. The resupply of serviceable engines at the base level is based upon historic usage and repair patterns. This is intended to be the basis for routine shipments. From time-to-time surges in flying activity may cause the serviceable inventory of engines to be depleted to the point of affecting mission capability. This situation is commonly referred to as "Not Mission Capable Supply" (NMCS). The existence of a NMCS situation will cause the levying of a mission

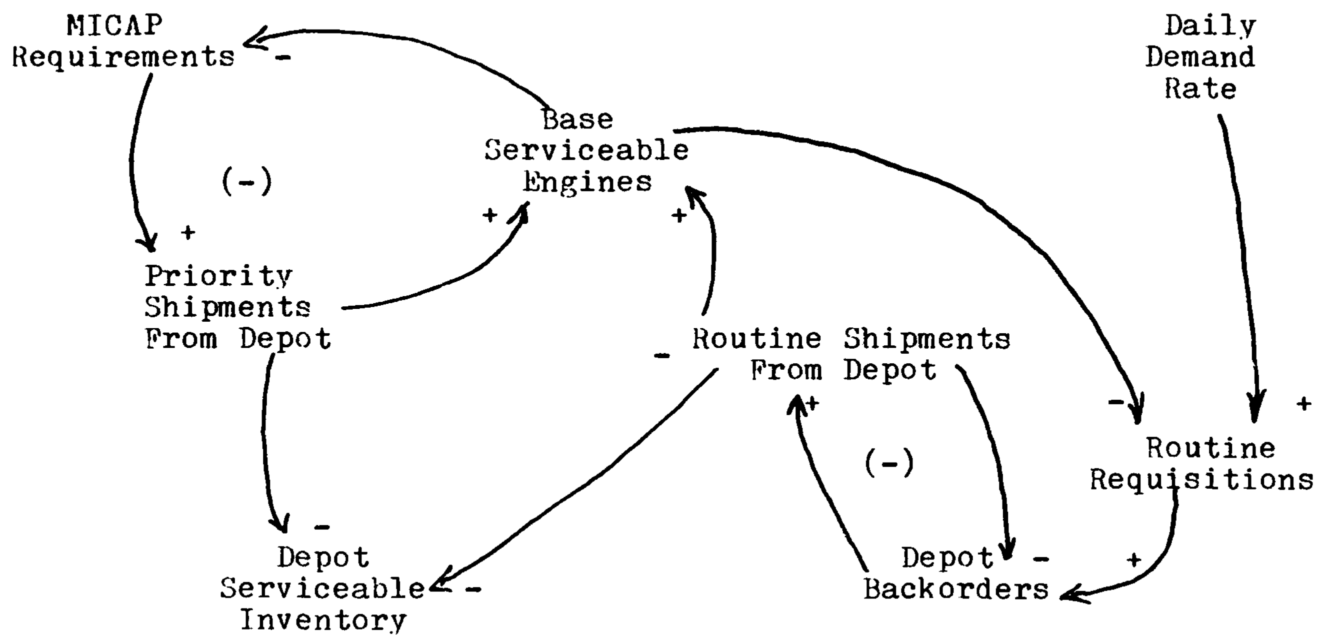


Fig. 3-24. Causal-Loop Diagram for the Depot Resupply Process Sector

capability (MICAP) requirement on the depot serviceable inventory. Satisfaction of a MICAP requisition is by priority shipment.

From this causal-loop diagram a flow diagram of the sector was developed. This flow diagram will be discussed next.

Flow Diagram of the Depot Resupply Process

Figure 3-25 is a flow diagram of the depot resupply sector. Engines move from the depot serviceable inventory (DSI) at the rate of priority shipments from depot (RPSFD) into the priority shipments in transit level (PINTRL). From this level, engines move into the serviceable inventory of engines (SINVE) through a third-order delay, the rate of arrival of priority shipments from depot (RAPFD).

Engines also move from the depot serviceable inventory (DSI) at the rate of routine shipments from depot (RRSFD) into the routine shipments in transit level (RINTRL). From this level, engines move into the serviceable inventory of engines (SINVE) through a third-order delay, the rate of arrival of routine shipments from the depot.

This flow diagram is intended to depict the structure of the transportation network between base and depot. From this flow diagram, DYNAMO equations are

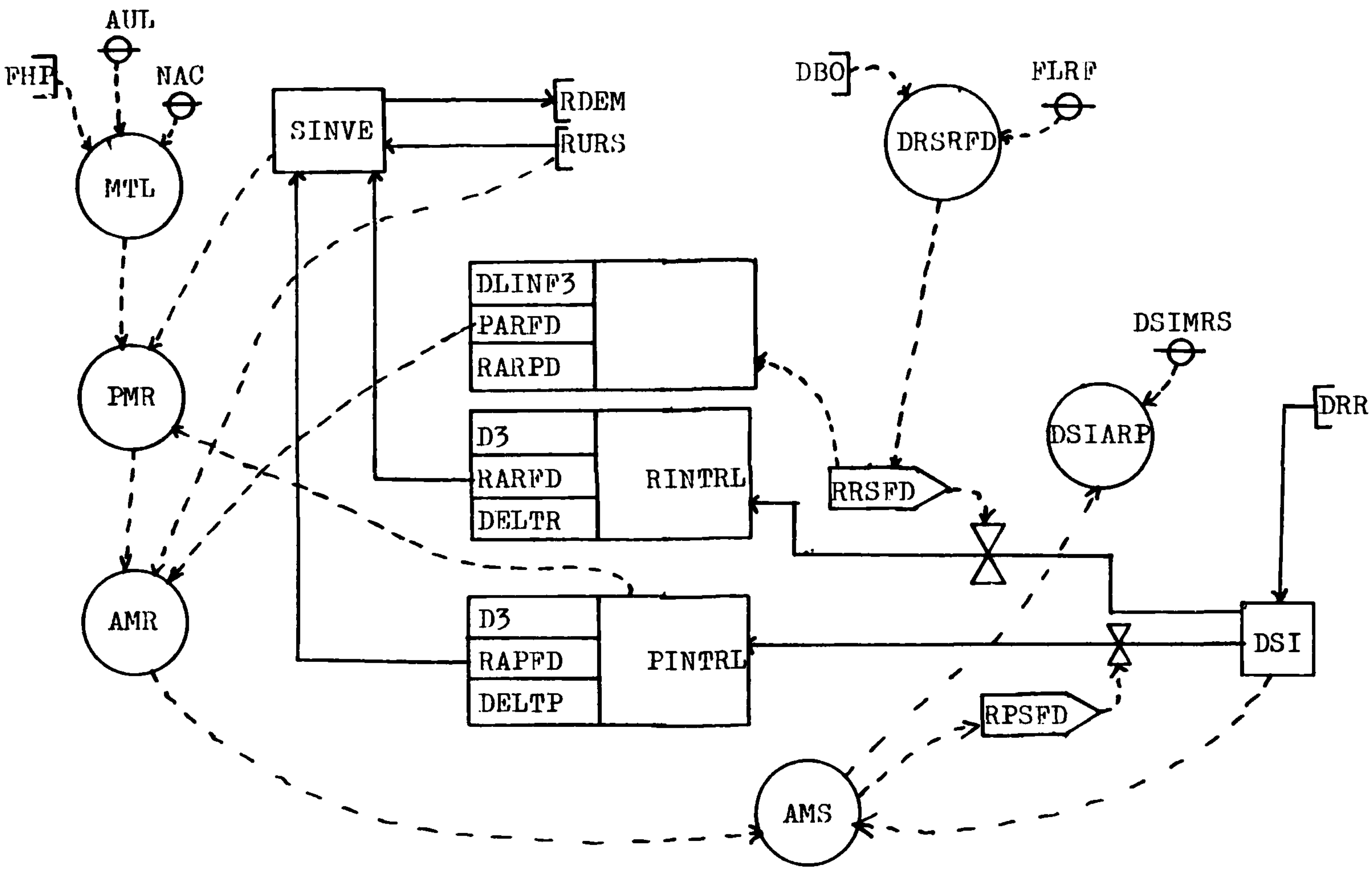


Fig. 3-25. Flow Diagram for Depot Resupply Sector

TABLE 3-8

Variables Appearing in Figure 3-25

MTL	-	MICAP THRESHOLD LEVEL (ENGINES)
FHP	-	FLYING HOUR PROGRAM (FLY HR/WK)
AUL	-	ABSOLUTE UTILIZATION LIMIT (FLY HR/AIRCRAFT/WK)
NAC	-	NUMBER OF AIRCRAFT (UNITS)
PMR	-	POTENTIAL MICAP REQUIREMENTS (ENGINES)
SINVE	-	SERVICEABLE INVENTORY OF ENGINES (ENGINES)
PARFD	-	PERCEIVED ARRIVAL RATE OF ROUTINE SHIPMENTS FROM DEPOT (ENGINES/WK)
RRSFD	-	RATE OF ROUTINE SHIPMENTS FROM DEPOT (ENGINES/WK)
RARPD	-	ROUTINE ARRIVAL RATE PERCEPTION DELAY (WKS)
AMR	-	ACTUAL MICAP REQUIREMENTS (ENGINES)
RURS	-	RATE AT WHICH UNSERVICEABLES RETURN TO SERVICE (ENGINES/WK)
AMS	-	ACTUAL MICAP SHIPMENTS (ENGINES)
DSI	-	DEPOT SERVICEABLE INVENTORY (ENGINES)
RPSFD	-	RATE OF PRIORITY SHIPMENTS FROM DEPOT (ENGINES/WK)
PINTRL	-	PRIORITY SHIPMENTS IN TRANSIT LEVEL (ENGINES)
RAPFD	-	RATE OF ARRIVAL OF PRIORITY SHIPMENTS FROM DEPOT (ENGINES/WK)
DELTP	-	PRIORITY TRANSPORTATION PIPELINE DELAY (WKS)
DSIARP	-	DEPOT SERVICEABLE INVENTORY AVAILABLE TO THE ROUTINE PIPELINE (ENGINES)
DSIMRS	-	DEPOT SERVICEABLE INVENTORY MICAP RESERVE STOCK (ENGINES)
DRSRFD	-	DESIRED ROUTINE SHIPMENT RATE FROM DEPOT (ENGINE/WK)
DBO	-	DEPOT BACKORDERS (ORDERS)
FLRF	-	FILL RATE FACTOR (WKS)
RINTRL	-	ROUTINE IN TRANSIT PIPELINE LEVEL (ENGINES)
RARFD	-	RATE OF ARRIVAL OF ROUTINE SHIPMENTS FROM DEPOT (ENGINES/WK)
DELTR	-	ROUTINE TRANSPORTATION DELAY (WKS)

developed. These equations will be discussed next.

DYNAMO Equations of the Depot Resupply Process

The mission capability threshold limit (MTL) is determined by a minimum function. MTL is the minimum of the flying hour program (FHP) divided by 0.7 times the absolute utilization limit (AUL) or the number of assigned aircraft.

```
A         MTL.K=MIN(FHP/0.7*AUL),NAC)
```

The potential MICAP requirements (PMR) is the maximum of the MTL minus the priority shipments in transit level and the serviceable inventory of engines or zero. A maximum is used to avoid having a negative MICAP requirement.

```
A         PMR.K=MAX((MTL.K-(PINTRL.K+SINVE.K)),0)
```

The purpose of these two equations is to capture the decision structure involved in making MICAP assessments. This structure is used to show that PMR is a function of the flying hour program and the number of assigned aircraft.

The perception of an occurrence is nearly as important as the actual occurrence. For this reason, the perceived arrival rate of routine shipments from depot (PARFD) is calculated as a third-order information delay of the rate of arrival of routine shipments from the depot (RRSFD) over the routine arrival rate perception delay

(RARPD) of 1.5 weeks. This value is used in the derivation of the actual MICAP requirements (AMR). Listed below are the equations used to derive PARFD and AMR.

```
A         PARFD.K=DLINF3(RRSFD.JK,RARPD)
C         RARPD=1.5
A         AMR.K=MAX((PMR.K-RURS.JK*DELTP-PARFD.K*DELTP),0)
N         AMR=0
```

The purpose of this string is to show the decision structure involved in filling MICAP orders. A minimum function, between actual MICAP requirements (AMR) and depot serviceable inventory (DSI), is used to avoid shipping out more engines than the depot possesses.

```
A         AMS.K=MIN(AMR.K,DSI.K)
```

The rate of priority shipments from depot (RPSFD) is equal to the actual MICAP shipments divided by the computation interval (DT). These shipments are the inflow to the priority in transit level. Engines leave the priority in transit level at a rate equal to the rate of arrival of priority shipments from depot (RAPFD). RAPFD is a third-order delay over one week. This formulation is used to capture the movement of engines between depot and base in a priority status. These equations are listed next.

```
R         RPSFD.KL=AMS.K/DT
L         PINTRL.K=PINTRL.J+DT*(RPSFD.JK-RAPFD.JK)
N         PINTRL=0
```

R RAPFD.KL=DELAY3(RPSFD.JK,DELTP)

C DELTP=1.0

At the same time as MICAP orders are being filled, the routine requisition process is also taking place. This process begins with the development of a rate of routine shipments from the depot (RRSFD). The first variable developed is the depot serviceable inventory available to the routine pipeline (DSIARP). DSIARP is obtained from a maximum function. The function chooses between zero and the depot serviceable inventory minus the depot serviceable inventory MICAP reserve minus the actual MICAP shipments. This formulation avoids negativity and assures MICAP requirements will be met first. It is an attempt to indicate that MICAP requirements will be satisfied before routine requirements.

The desired routine shipments rate from the depot (DRSRFD) is developed as the level of depot backorders (DBO) divided by the fill rate factor (FLRF) of 0.4 weeks. This is used to show the manager's desire to spread the use of inventory over time.

The rate of routine shipments from the depot (RRSFD) can now be developed using the FIFGE macro. The macro is developed so as to return the value of DSIARP/DT or DRSRFD, as appropriate. This formulation is intended to show that RRSFD is a function of the inventory available and the number of backorders in the system. The equations which yield RRSFD are listed next.

```
A          DSIARP.K=MAX((DSI.K-DSIMRS.K-AMS.K),0)

C          DSIMRS=1

A          DRSRFD.K=DBO.K/FLRF

C          FLRF=0.4

R          RRSFD.KL=FIFGE(DSIARP/DT,DRSRFD,DRSDFD,
              DSIARP.K/DT)
```

The change function for the routine shipments in transit level (RINTRL) is equal to the rate of routine shipments from depot minus the rate of arrival of routine shipments from the depot (RRSFD-RARFD). The equations for RINTRL are listed here.

```
L          RINTRL.K=RINTRL.J+DT*(RRSFD.JK-RARFD.JK)

N          RINTRL=0
```

The arrival rate of routine shipments from depot (RARFD) is a third-order delay of RRSFD over the routine transportation delay (RTD) of one week. This equation is listed below.

```
R          RARFD.KL=DELAY3(RRSFD.JK,DELTR)

C          DELTR=1.0
```

The purpose of this formulation is to show the structure of the resupply process. It is set up so that priority requisitions are filled first. Routine requisitions are filled with the remaining inventory.

This section has presented the depot resupply sector. The flow diagrams and DYNAMO equations were presented and discussed.

Summary

This chapter has presented the computer model, developed by Trichlin and Trempe (25:Ch.3), which will be used to study the engine management system. Although a complete model was available, the structure of the model had to be dissected in order to ensure the model did, in fact, mirror the system.

The structure of the system was obtained through interviews with system managers, personal experience and a literature review. This parameters used in the model came from the systems standard values for repair and transportation times found in AFM 400-1.

A complete listing of the causal diagrams can be found in Appendix A. Appendix B contains the flow diagrams. Appendix C is a listing of system equations.

Discussed in the next chapter will be the operation of the computerized model.

CHAPTER 4

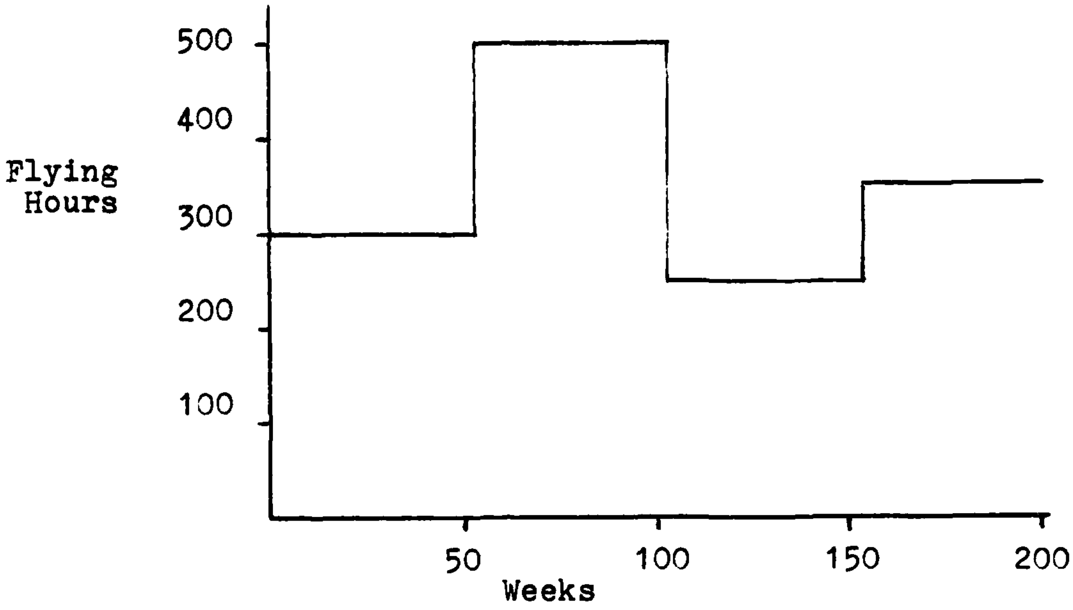
VALIDATION

Overview

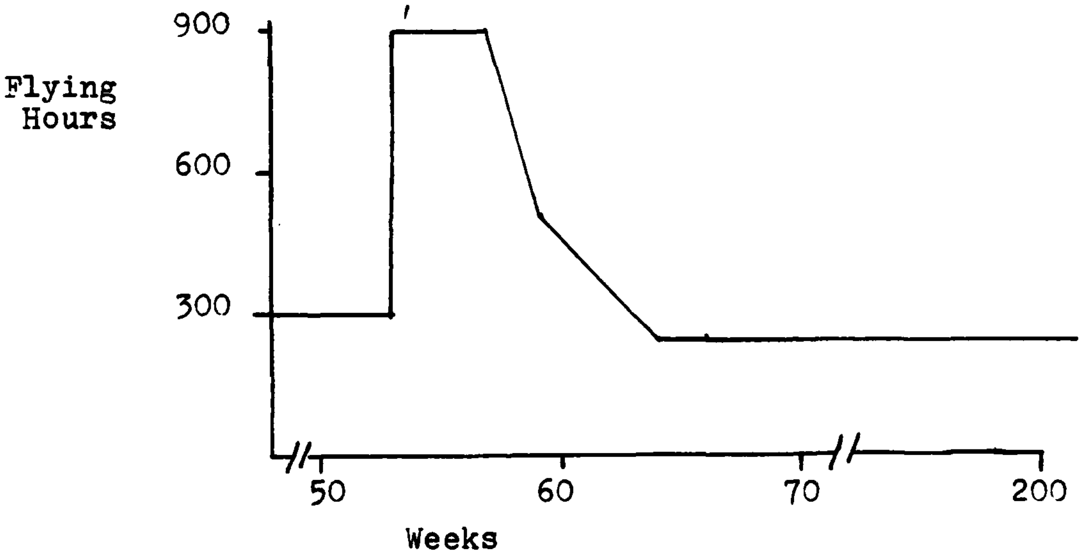
There are several ways to study the impact of policy changes with a system dynamics model. Changing parameter values, changing model structure, or varying the model's input function are three methods. Experimentation with this model will be performed by varying the input variable, the flying hour program. Additionally, for the second experiment some changes in model structure will be introduced.

Discussed in this chapter are the results obtained by testing the operation of the model using two different flying hour programs. The first of these two programs is a scenario simulation approximately four years of peace-time operations. As shown in Figure 4-1 the flying hour program fluctuates mildly, this is intended to represent changes in the flying hour program which might come about due to budgetary considerations, politics, or a perception of decreased threat.

Figure 4-1 also shows the other flying hour program which will be used to test the system. In this case a wartime scenario is used. This scenario, is as follows: at the beginning of week 53 a war begins and the flying hours per week goes from 300 to 900. This is



Experimental Run 1



Experimental Run 2

Fig. 4-1. Flying Hour Program for Experiments 1 and 2 accomplished by stepping the flying hours per week by 600 hours per week. This level, 900 hours per week, is maintained for a period of four weeks. After four weeks have passed, the flying hours are decreased by a ramp function at a rate of 200 hours per week. This is done for two weeks after which the decrease is slowed to 50 hours per week until the flying hour program is equal to 250 hours per week. This is the typical scenario for a short, conventional war in Western Europe found in defense related literature.

Because the purpose of the model was to observe the effects of pipeline times on the availability of engines at base level the following variables will be concentrated on:

The unserviceable inventory of engines (USINVE). This quantity should remain at or near zero. In the real world system engines are rarely kept waiting for repair.

The serviceable inventory of engines (SINVE). The engines in this system are used on the F-4 aircraft, a twin engine fighter. The model was developed using a hypothetical wing of 72 aircraft. This means that 144 engines are required to keep all 72 aircraft serviceable. For the purpose of this model a serviceable aircraft is defined as one with two serviceable engines. If the system is operating "correctly" then SINVE will remain at some value above 144. The excess of 144 are used as spares.

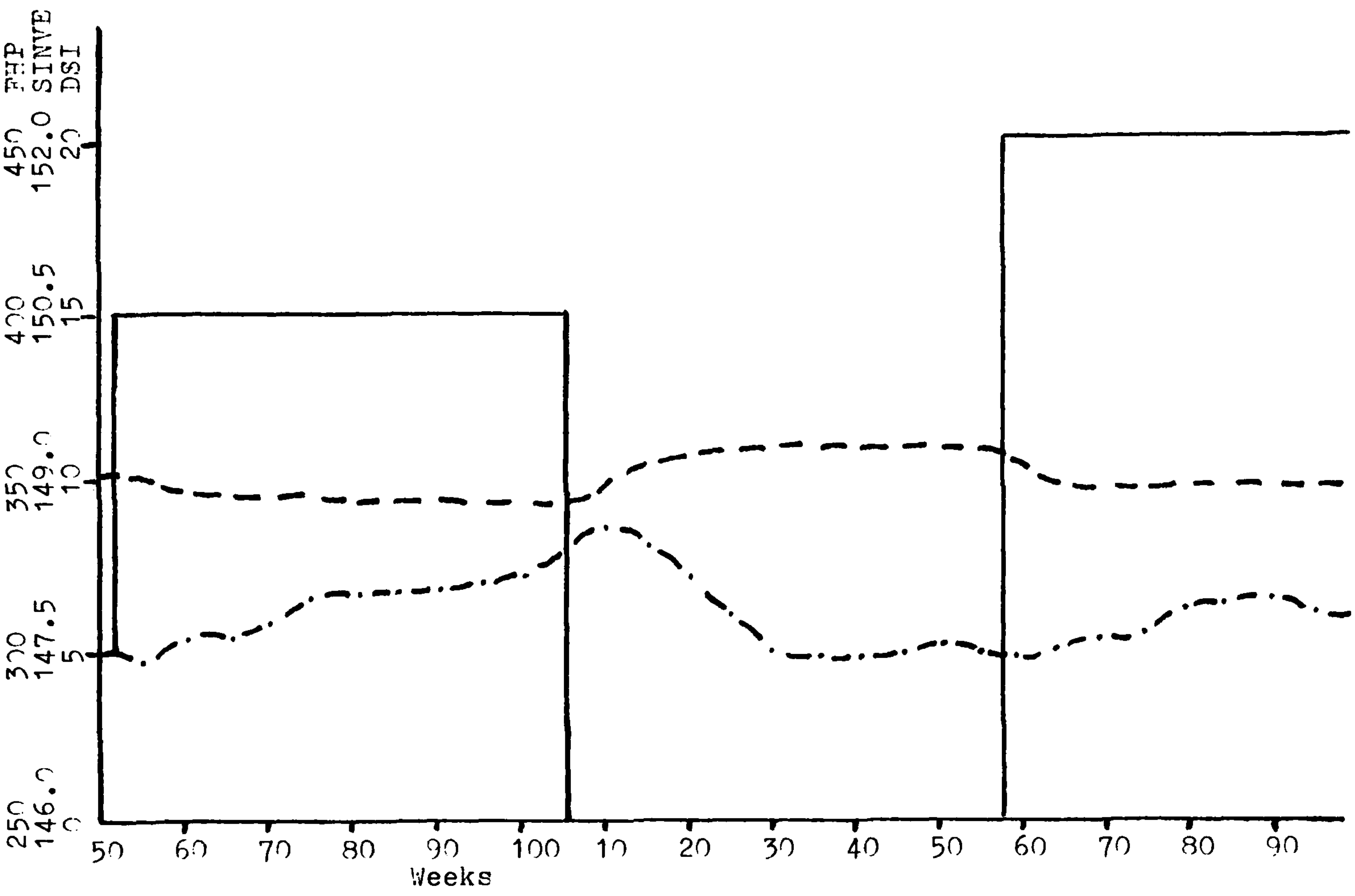
Depot serviceable inventory (DSI) is important because in the event of surges in the use rate, this inventory would be used to fill any need for engines which might be necessary to satisfy the flying hour program. The value of this inventory should remain above zero.

The rate of demand for engines (RDEM) is an indicator of how many engines are being used to perform the assigned mission. It will be compared with the perceived weekly demand rate (PWDR) in order to get an idea of the difference between what managers perceive and what is actually going on.

In any simulation model there is a certain amount of time at the beginning of the simulation run which is needed to allow the system to reach normal operating conditions. In the case of this model, a moving average over 180 days was used to derive several variables. Since 180 days do not pass until after the first 26 weeks, this first 26 weeks will be disregarded. Discussion of the model's output will begin at week 26 or later.

Experimental Run 1

The results of this simulation run, relative to SINVE and DSI, are shown in Figure 4-2. The vertical axis of the graph has a different scale for each variable. As the graph shows, SINVE varies only slightly more than DSI. This would indicate that the system accomodates sudden



LEGEND: FHP: ___, SINVE: _._._, DSI: _ _ _ _

Fig. 4-2 Results of Experimental Run 1

change in the flying hour program very well. A more detailed discussion of the run is presented in the next section.

Discussion of Experimental Run 1

Week 30 to 40. During this time period, the flying hour program is at 300 hours per week. The unserviceable inventory of engines is essentially at zero. This is because managers will not wish to keep unserviceable engines lying around. These engines will be boxed and shipped to the depot or put into base level repair immediately. There is one engine in the under repair inventory. Ten engines are in the depot serviceable inventory while two are in the depot unserviceable inventory. There are 72 serviceable aircraft at base level.

Also during this period the perceived and actual total base assets (PTBA, ATBA) are equal at 149.

Week 40 to 50. During this time period, the model is still in equilibrium, the rate engines are declared NRTS is showing an increase but this is only from 12.5% to 15.0%. The depot serviceable inventory (DSI) is also showing a change. In this case it is decreasing, and there is a corresponding increase in the routine shipments in transit level (RINTRL). This indicates engines moving from the depot to base level in order to satisfy orders from the base. The rate of demand for engines (RDEM) is at .74 with the perceived weekly demand rate (PWDR) lagging behind at .61. This should cause no problems in system operation as long as PWDR starts to follow RDEM.

Week 50 to 60. At the beginning of week 53, the flying hour program goes from 300 hours per week to 400 hours per week. This causes a decrease in the number of base compressors. The number of serviceable engines also begins to decrease but is brought back up almost immediately. This is due to the arrival of shipments from the depot. The unserviceable inventory of engines also starts to increase but is pulled back to near zero by an increase in the rate unserviceables go under repair. During week 55 the rate of demand for engines is at 1.0 while the perceived weekly demand rate is at .66. This would indicate that managers will not change their perception of demand unless changes in use rates appear to be long-term. By the sixtieth week the system is beginning to show signs of recovery from the change in the flying hour program.

Week 60 to 70. During this time period, the system continues its recovery from the step in the flying hour program. The serviceable inventory of engines is at 148 and remains at that level throughout the period. The NRTS rates for both engines and compressors show an increase followed by a decrease. This is due to the effects of the change in the flying hour program in week 53.

Both the rate of routine shipments from the depot and the arrival of these shipments show an increase then decrease as the system corrects for the change in the flying hour program. Perceived demand and actual demand continue to move closer together and by week 70 are at .83 and .86 respectively. This indicates that the manager is readjusting his perception to more closely mirror reality.

Week 70 to 104. Throughout this period, the system appears to have fully recovered from the "shock" of the sudden change in the flying hour program.

Week 105 to 110. At the beginning of week 105, the flying hour program is decreased to 250 hours per week. As would be expected the NRTS rate for engines and compressors drops with the lower flying hour pressure. Also, the compressor inventory at base level increases. There is a decrease of one serviceable engine at base level. This would be explained by an engine moving from base to depot level repair. Both the routine shipments from depot and the arrival of those shipments (RRSFD, RARFD) goes to zero during this time period. This would be expected, since if the pressure is suddenly decreased, a slackening of most work would occur. This behavior is also exhibited by the rate of demand and the engine repair rate. However, the perception of demand remains at .82, near its previous level of .85. This is expected since managers will not change their perception until evidence indicates a change in demand is likely to persist.

Week 110 to 120. During this time period, the depot serviceable inventory goes from 10 to 11 and base serviceables go from 149 to 148. This change in serviceable engines can be attributed to usage. The depot compressor inventory continues to decrease but it appears to be stabilizing. Both NRTS rates, engines and compressors, have leveled off and remain constant throughout the period. The rate of demand remains at .5 throughout this period. The perceived demand rate, however, drops from .82 at week 110 to .65 at week 120. Shipments from the depot and their arrival show a change from zero at week 117. The changes in perceived demand and the movement of engines between depot and base indicate that the system has caught up with the change in the flying hour program.

Week 120 to 156. During this period, the system has reached equilibrium. All of the variables remain relatively constant over the entire period.

Week 157 to 170. At the beginning of this time period, the flying hour program increases to 350 hours per week. The NRTS rates for both engines and compressors begins an increase, but during the period from week 160 to 170 they begin to level off. Shipments, and their arrival at base level, also show a sharp increase and then begin to level off between week 160 to week 170. As expected, the rate of demand leads perceived demand by .70 to .60 at week 165.

Week 170 to 180. During this period, the system continues to attempt to correct for the "shock" of an increase in the flying hour program. The NRTS rate for both engines and compressors, after a slight increase show a drop. Both routine shipments and their arrivals show a decrease during this period.

Week 180 to 200. During the remainder of the run, the system has recovered from the effects of the change in the flying hour program. While there are some changes, the variables are for the most part stable.

Summary of Experimental Run 1

The model appears to mirror the operation of the real world system. At no time did the number of serviceable aircraft fall below seventy two. This is because there are more spares at base level than required. If serviceable engines had been set at 144, then over the period of the run discussed there would never have been more than 71 serviceable aircraft or less than 70. By the same token, if four spare engines had been available no aircraft would have been grounded for lack of an engine. Neither of these two scenarios accounts for unforeseen surges in demand or use. It can be safely stated however, that for this type of scenario five to six spare engines would provide an adequate safety margin for peacetime operations.

Perceived demand followed changes in actual demand. This would be expected as managers will be slow to change perception of demand unless confronted with evidence that indicated the actual demand change would be long-term.

The system appears to recover better from a decrease in the flying hour program than an increase. This would be true in the real world also, since it is easier to decrease the work rate than to increase it.

Experimental Run 2

In order for the model to simulate a wartime scenario several changes to model structure were made. The first was a change in the equation for the flying hour program (FHP). It became:

```
A        FHP.K=300+STEP(600,53)-RAMP(200,57)+RAMP(150,59)+
             RAMP(50,64)
```

The second was to change proportion of engines to depot from a constant to an auxiliary variable. This was done using the step function:

```
A        PROPD.K=.2+STEP(.8,53)-STEP(.2,57)-STEP(.4,59)-
             STEP(.2,64)
```

This is used because it is likely that no engines will be repaired under the high workload which would be encountered during the early stages of combat. As time passes, and mobilized reservists begin arriving the forward location will be able to start picking up some of the repair load. As time passes and the flying hour program decreases, more and more engines will be repaired at the forward location.

The compressor repair process is handled in much the same way. However, since only 10 percent of compressors are repaired at base level, the compressor repair process is not accepted until week 65. The following equation is used to represent this process.

A PCPD.K=.9+STEP(.1,53)-STEP(.1,65)

The following changes were also made:

The variable, base engines (BE), was set at 159. This was done to represent the war reserve material which would be made available to units engaged in combat operations.

The minimum depot repair delay was shortened from 3.5 weeks to 1.75 weeks, and, the depot maximum throughput was increased to .8 engines per week. These numbers were used to represent the increase in output which will come about under a contengency situation. They also represent resource constraints which would not allow for a greater output. These constraints are mainly due to personnel and time.

The following changes were made in the routine and priority pipeline times. The routine pipeline delay was changed from 1 week to .572 weeks or 4 days. The priority pipeline delay was changed from 1 week to .285 weeks or 2 days. This was done to represent the speed up in transportation expected during a contingency. Priority shipments of engines would be sent out on the first aircraft, and routine shipments would go out within three or four days of an order receipt.

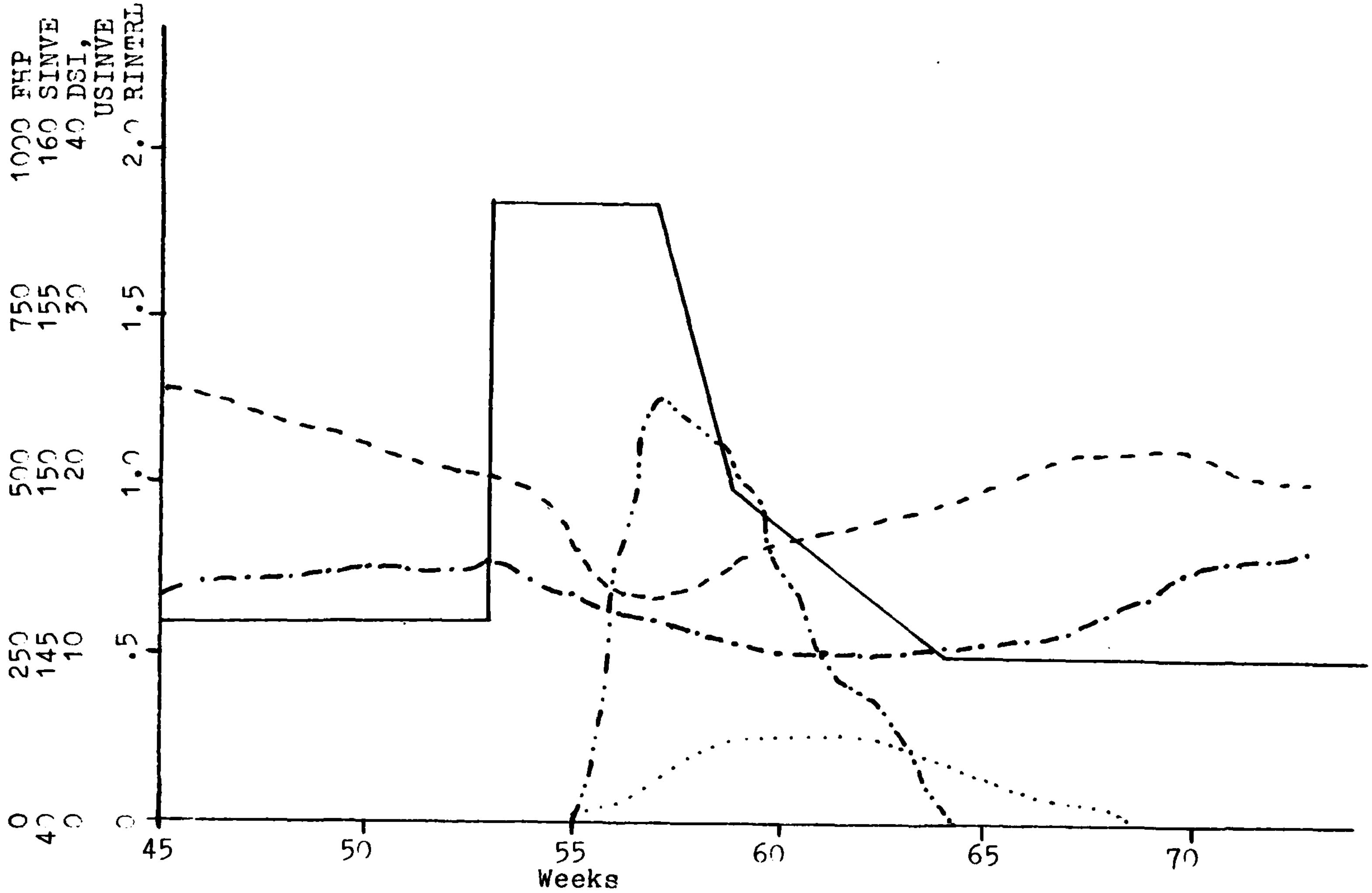
The results of experimental run 2, relative to SINVE, USINVE, DSI, and RINTRL are shown in Figure 4-3. Of particular note, is the plot for USINVE. This is the same shape which was related during interviews with a system manager (15). A detailed discussion of the results of this run is presented in the next section.

Discussion of Experimental Run 2

Week 45. There are approximately 153 serviceable engines at base level. Adding the one engine in maintenance leaves a total of 154 engines at base level. The depot possesses 16 engines, 15 of which are serviceable. Actual demand is at .66 while perceived demand is at .60.

Week 52. The flying hour program is at 300 hours per week. There are 152 engines at base level, one of these is in the under repair inventory. This leaves 17 engines at the depot, 16 of which are serviceable. Actual demand is at .77 while perceived demand is at .63.

Week 53. The flying hour program has been boosted to 900 hours per week in an attempt to simulate a wartime



LEGEND: FHP: ___, SINVE: _ _ _, USINVE: ...., DSI: _ . _, RINTRL: _.._

Fig. 4-3 Results of Experimental Run 2

scenario. The base has 152 engines but two are in the under repair inventory. This indicates the arrival of an engine from the depot since the last period. The actual rate of demand has gone to .80, while the perceived rate has only increased to .64.

Week 55. The actual demand for engines per week is at 2.2 engines per week, while perceived demand is now at .72. At this time there is beginning to be a buildup of engines in the unserviceable inventory of engines (USINVE). There are also 2 engines in under repair inventory one (URINV1). In this case, URINV1 represents engines being prepared for shipment to the depot.

Week 56. The demand for engines has started to decrease and now stands at 2.16. There are 146 serviceable engines at base level. In the three week period since the "war" started, this inventory dropped by 6. This indicates that at least 6 spare engines would be required to support this type of flying hour program and keep all 72 aircraft serviceable. Additionally, there should be one or two engines extra to serve as a safety stock. This is also the lowest level that SINVE reaches in the run.

Week 58 to 60. The flying hour program goes from 700 hours per week, at the beginning of this period, to 450 hours per week, at the end of the period. Additionally, the base is beginning to pick up some of the repair load. By the end of week 60, the proportion of engines going to the depot is at 40%.

Week 61 to 62. As would be expected, perceived demand has moved ahead of actual demand by .99 to .86. This is due to the decrease in flying hour pressure. By the end of week 62, the flying hour program is down to 350 hours per week.

Week 63 to 70. During this time period, the base serviceable inventory of engines increases from 148 to 150. The backlog of unserviceable engines is decreased to zero. By the end of week 70, the system has reached equilibrium. The two exceptions are perceived and actual demand. This is due to the managers unwillingness to change his perception until he is certain the demand change will be long-term. All other variables are stable.

Summary of Experimental Run 2

This was an experimental run using a hypothetical flying hour program to simulate a wartime scenario. As such, it was an extremely one dimensional look at a wartime environment. The impact of combat conditions other than an increased flying hour program was not considered. This point will be discussed in the recommendations section of the next chapter.

Under the scenario the system functioned and kept a supply of serviceable engines at base level. A run of this scenario, with the flying hour program allowed to continue at 900 hours per week for 8 weeks, returned virtually the same results.

In terms of varying the pipeline times, the results were basically the same as reported here, however, the variations in inventory between extremes were larger for longer pipeline times and smaller for shorter times. This is similar to the behavior Forrester reported for changes in multi-echelon system delays (5:33).

Chapter Summary

This chapter has presented the results of the model's operation. Two scenarios were used. In the first, the flying hour program was varied slightly once every 52 weeks. The purpose of this run was to test model behavior relative to the real world system. The operation of the model was similar.

The second scenario was a hypothetical wartime flying hour program. Again the model acted in much the same manner as would be expected from the real world system.

Output from the two runs presented in this chapter can be found in Appendix D, for run 1 and Appendix E, for run 2. The next chapter summarizes the research and presents conclusions and recommendations for further study.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

The objectives for this research were stated in chapter one. These objectives are restated below:

1. Identification of the major process of the engine management system;

2. Analysis of the elements of these processes, their structure and relationships, and the attributes of these elements and relationships;

3. Development of a mathematical model which mirrors the engine management process;

4. Development of a computerized model from the mathematical and system dynamics models of the system;

5. To verify the performance of the model and validate that the model represents the system;

6. To evaluate the model as a policy development and analysis tool;

7. To identify areas of concern for policy makers (5:13).

This chapter presents a summary of the research effort as it pertains to each of these objectives. Conclusions about the model's performance and the engine management system in general are presented next. The final section presents recommendations for future research with the model.

Summary

The first objective of this research was to identify the major processes of the engine management system. This was done through personal experience with the system, interviews with system managers and a literature review. The major processes of the engine system were identified as; base repair, depot repair, base requisition, depot resupply and demand generation. The satisfaction of the first objective allowed the research to proceed to the next objective.

The second objective was analysis of the major processes. This analysis involved defining the structures of the various processes and what the relationships between these processes were. Completion of this analysis allowed the study to proceed to the third objective.

The third objective of the research effort was the development of a mathematical model which represented the engine management system. Because of the work done on the first two objectives an existing model was found which was close in structure to the engine management system. This is the model developed by Trichlin and Trempe (25:Ch.3). This choice is valid because the two systems are "family systems" as defined by Forrester and Senge. The structure of the model was checked line for line a-gainst the structure of the engine system. Several changes were made in order to more closely align the model's structure with the structure of the engine management system. Satisfying this objective made the fourth objective relatively easy.

The development of a computerized model was the fourth objective of this research. Although this step was made somewhat easier by the decision to use the Trichlin and Trempe model (25:Ch.3), the structure of the computer model still had to be checked against the system structure. Each equation of the program had to be examined and its inclusion in the model justified. With a computerized model completed, the fifth objective could be addressed.

The fifth objective of this study was the verification and validation of the model's performance relative to the real world system. Using a hypothetical flying hour program, this was done in experimental run 1. Achievement of the fifth objective allowed the research to proceed to objective six.

The evaluation of the model as a policy analysis and development tool was the sixth objective of the research. This was accomplished by running a simulation based on a wartime scenario. The results of this run were reported in chapter four.

Because of the work done on the first six objectives some degree of confidence in the model's structure was gained. This allows conclusions, based upon the model's performance, to be presented.

Conclusions

The results of this research indicate that the engine management system is a goal-oriented, feedback control system. The goal of this system is to make serviceable engines available at base level. While this goal is generally agreed upon, the means to accomplish it are not.

The goal of this research was to develop a system dynamics model of the engine management system. The model which is presented here satisfies this goal to the extent such a goal can be satisfied. This model can be used as a tool to assess the implications of current and proposed policy. This is especially true with regard to pipeline times and system parameters.

The model performed much as the real world system does relative to a peacetime scenario. It responded to the wartime scenario as expected. However, the only thing which can be stated with any certainty about this scenario is that it probably would not come about exactly as planned. The response of the model to changes in the pipeline times was similar to that reported by Forrester in his work with multi-echelon systems (5:33).

Because of the iterative nature of simulation modeling there can be no one final model of a system (5; 25). The mere act of building a model adds insights into system behavior which give rise to new questions about the system. This leads the analyst to studies of other policies within the system modelled. For this reason, recommendations for further study with this model will be presented next.

Recommendations for Further Study

Due to the iterative nature of model building, questions will arise during research which cannot be addressed due to time constraints. These questions can, however, be passed on to future researchers in the form of recommendations for further study.

The Base-Depot Interface

The model addresses the interface between one base and the depot. This is acceptable, since the transactions which occur between the base and depot are highly standardized. However, the addition of arrayed variables to the model would allow the study of interactions between several bases and the depot. Using this structure, the impact of different use rates at the various bases could be studied.

The Engine-Component Interface

The model, as presented, raises the relationship between only one component and the engine. Since every engine is made up of many different components the study of these relationships would likely be of some interest. Again, by adding arrays to the model's structure the interaction between the various components and the engine could be studied.

Personnel

The model addresses personnel only through the quality effects sector. The major reason for this was because the purpose of the model was to study the effects of pipeline times on the engine system. Personnel, however, should be included in the model in terms of experience, the number of personnel available, and a breakdown of the population in terms of skill. By skill is meant the skill level classification system used by the Air Force.

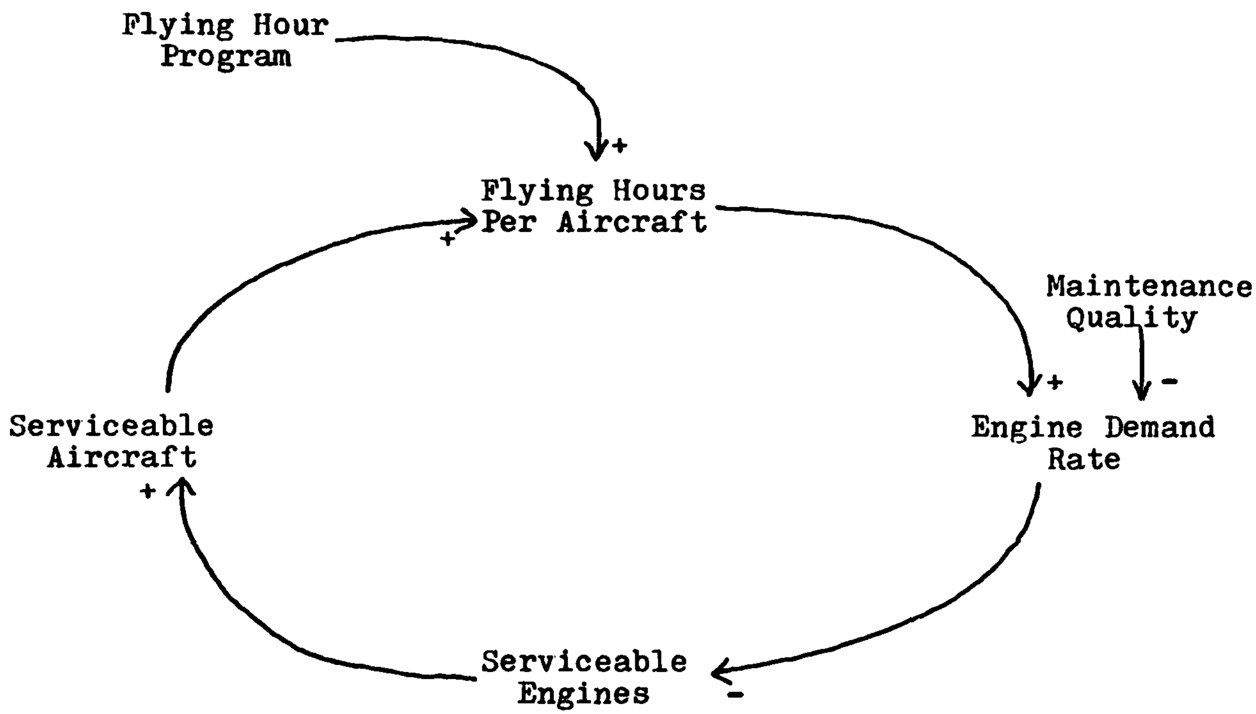
The Choice of an Engine

This model used the General Electric J-79-17 as the engine in the system. Since it might be more realistic to study the engine system in terms of the several components which make up each engine, it might be easier to use the F-100 engine as the representative engine in the system. The ease envisioned here would be in terms of data gathering on use rates.

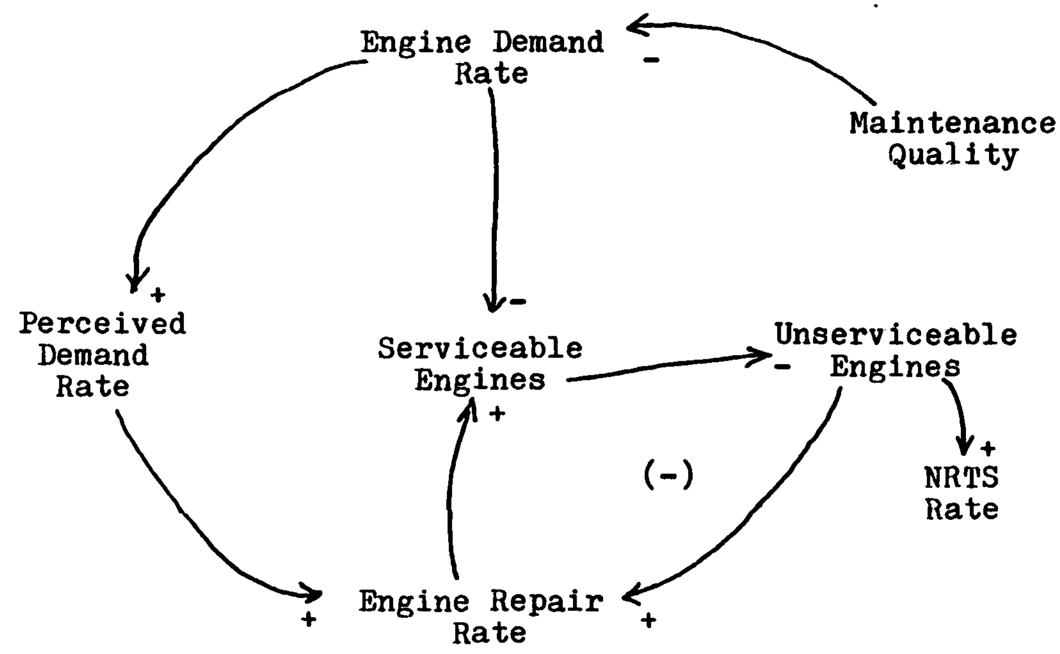
In summary, this model is a good first step towards a policy analysis tool for the engine management system. However, in order to realize its full potential the model must grow. The recommendations presented in this chapter point out several areas which will allow this model to be more fully developed as a true policy analysis tool.

APPENDIX A

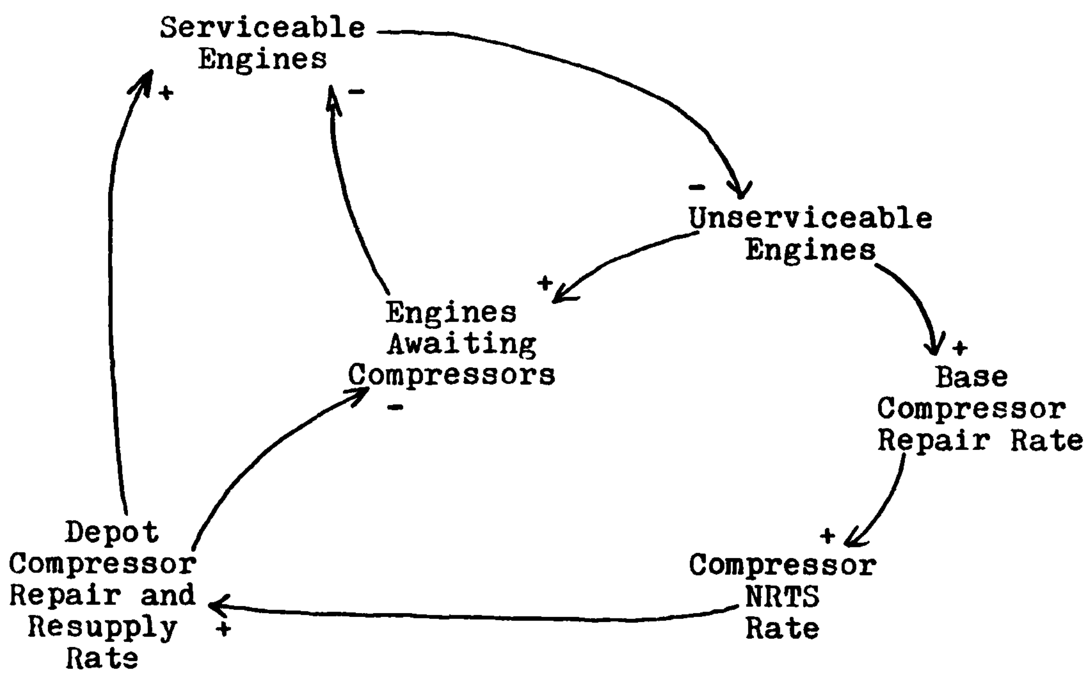
CAUSAL-LOOP DIAGRAMS



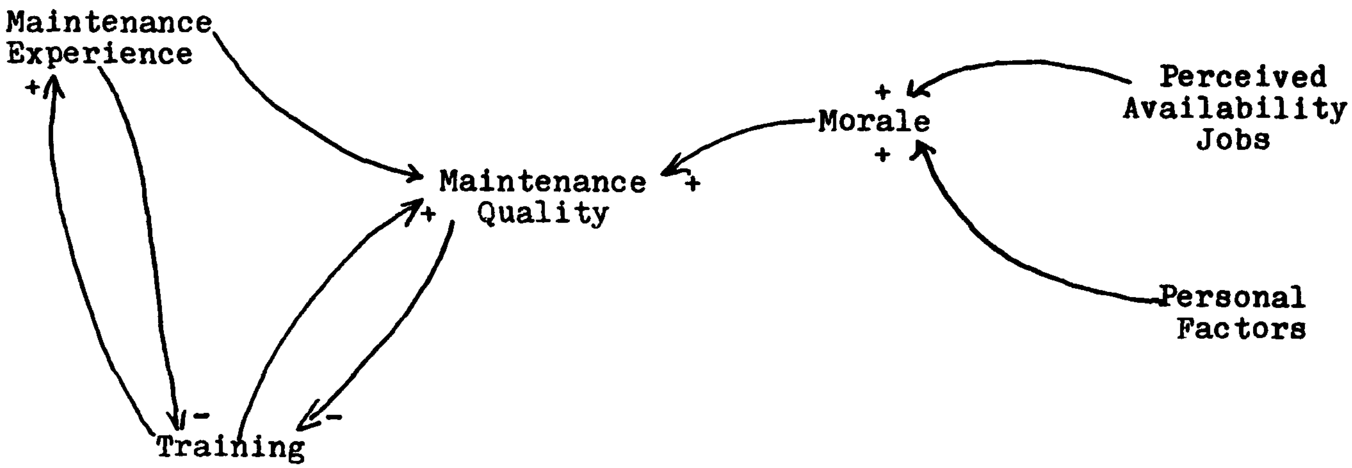
Causal-Loop for the Engine Demand Rate Sector



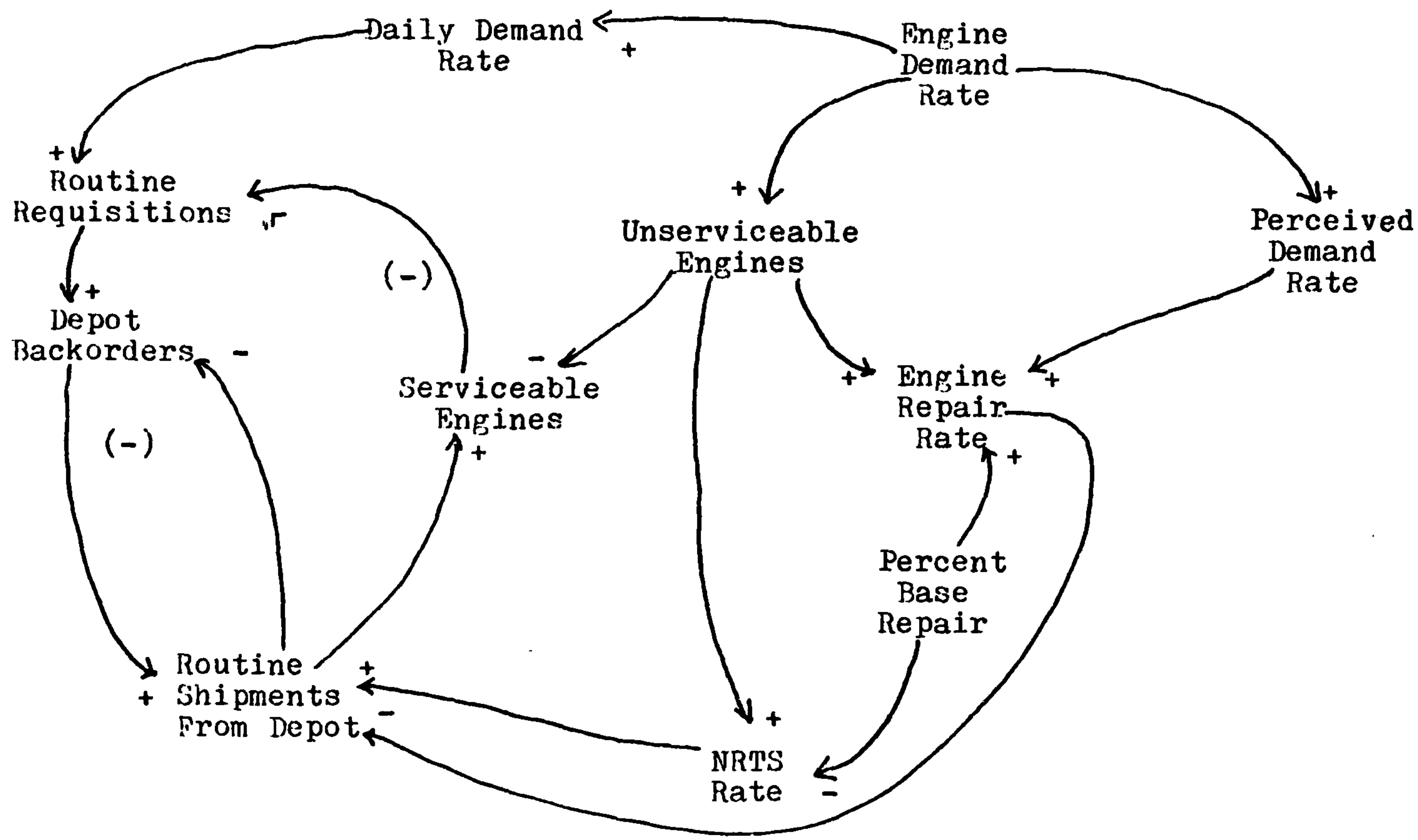
Causal-Loop Diagram for Base Engine Repair Process



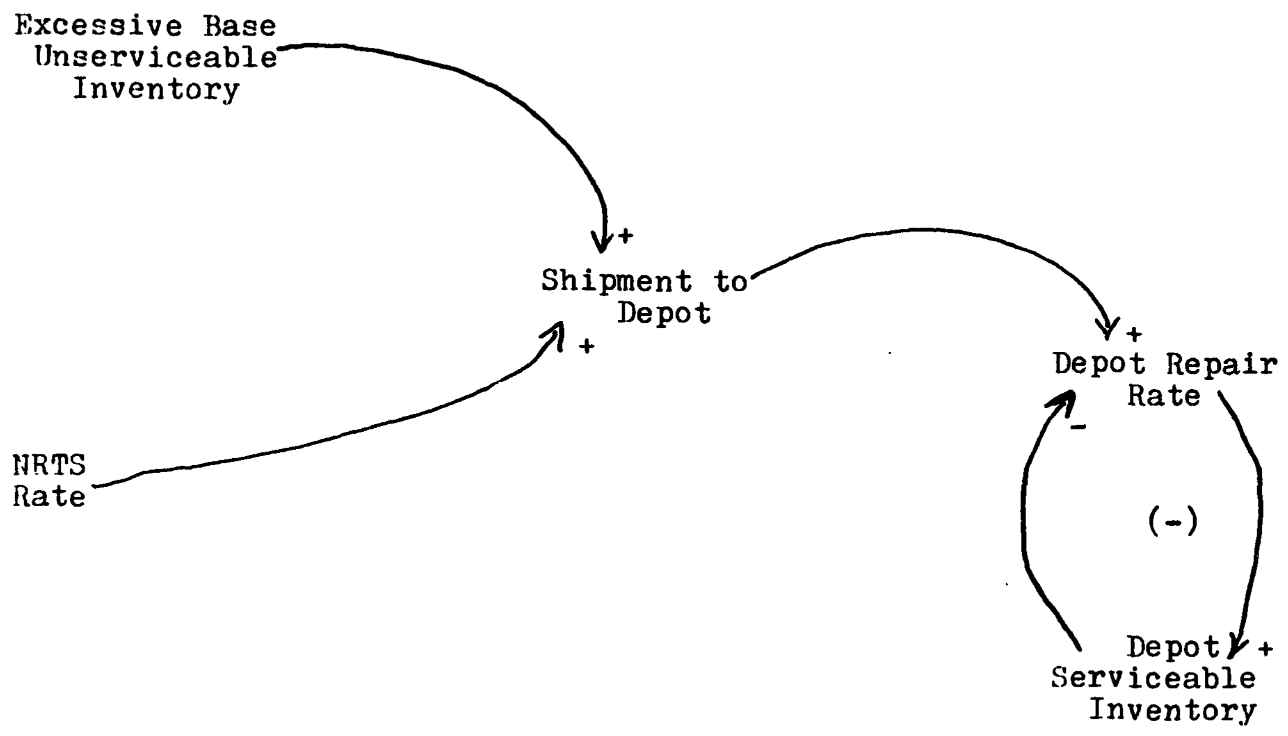
Causal-Loop Diagram for Base Compressor Repair Process



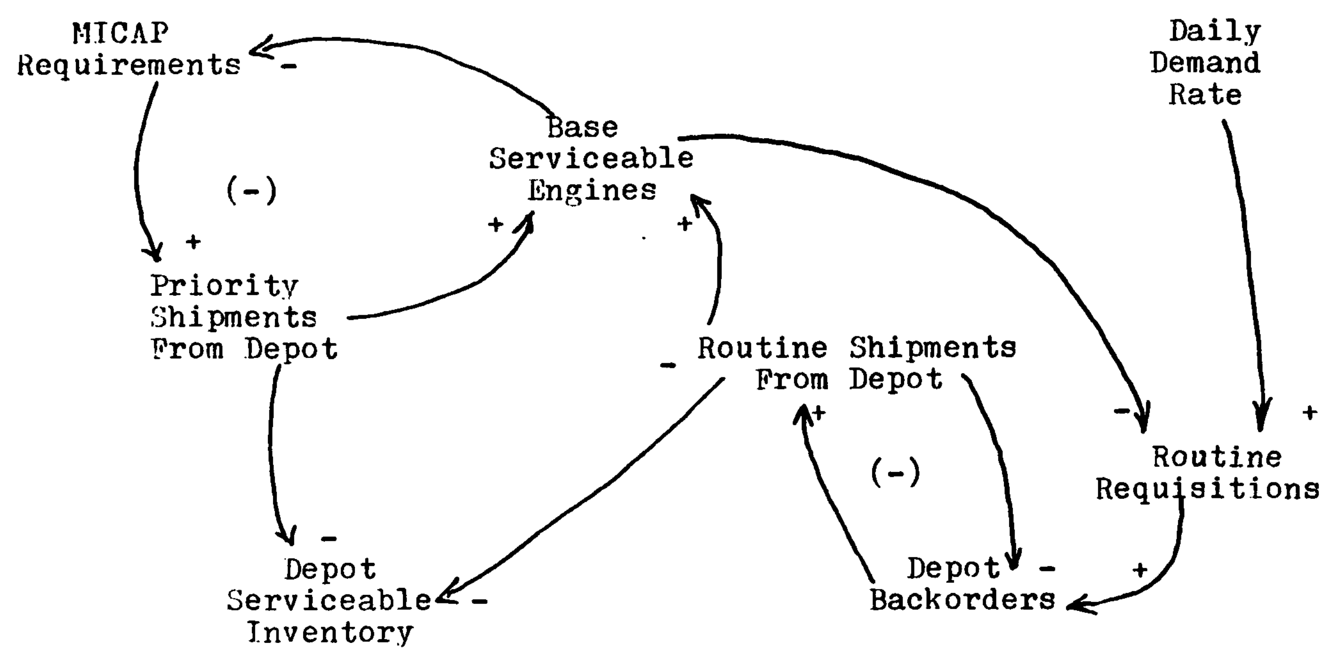
Causal-Loop for the Quality Effects Sector



Causal-Loop Diagram of the Base-Level Requisition Process Sector



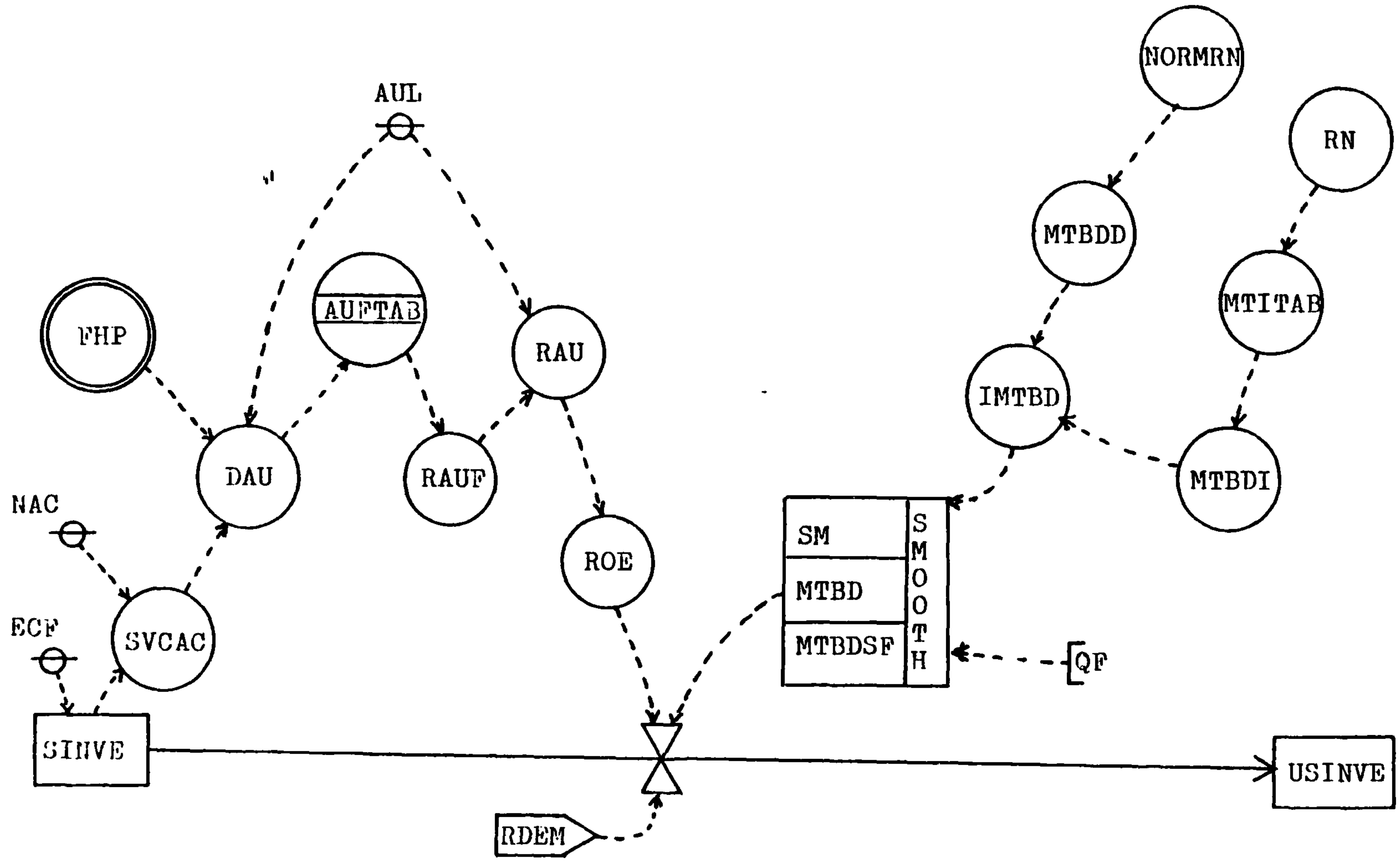
Causal-Loop Diagram for the Depot Repair Process Sector



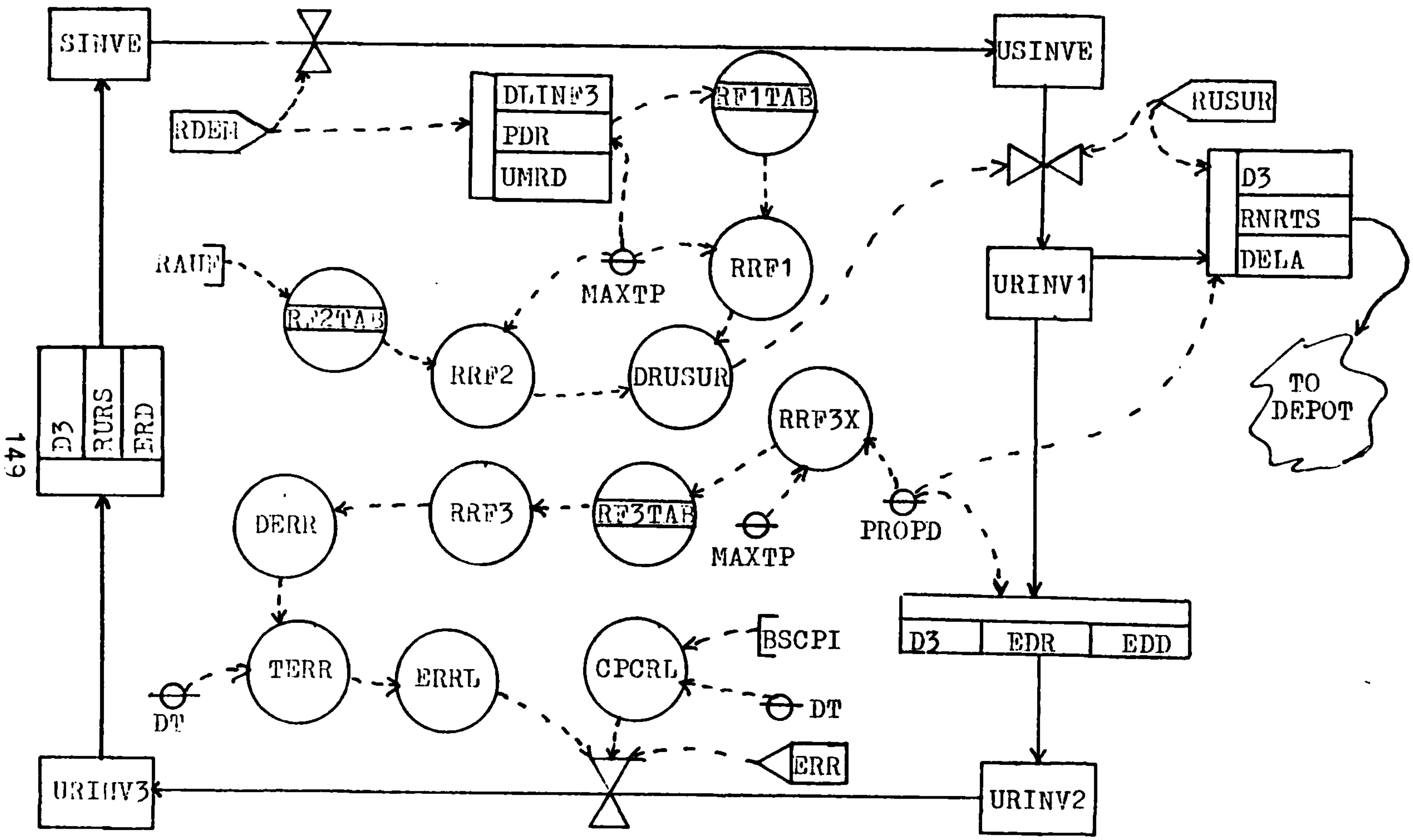
Causal-Loop Diagram for the Depot Resupply Process Sector

APPENDIX B

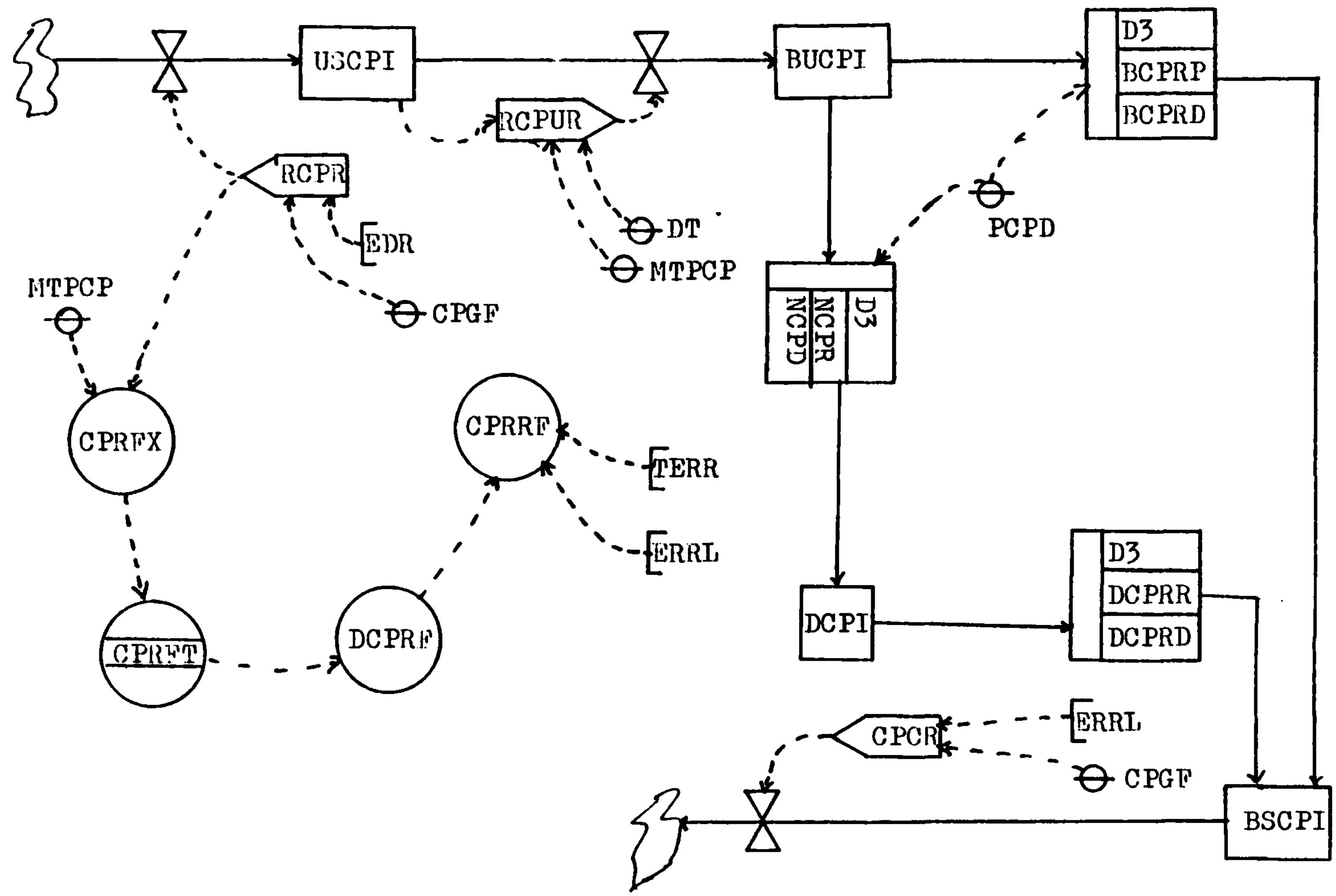
FLOW DIAGRAMS



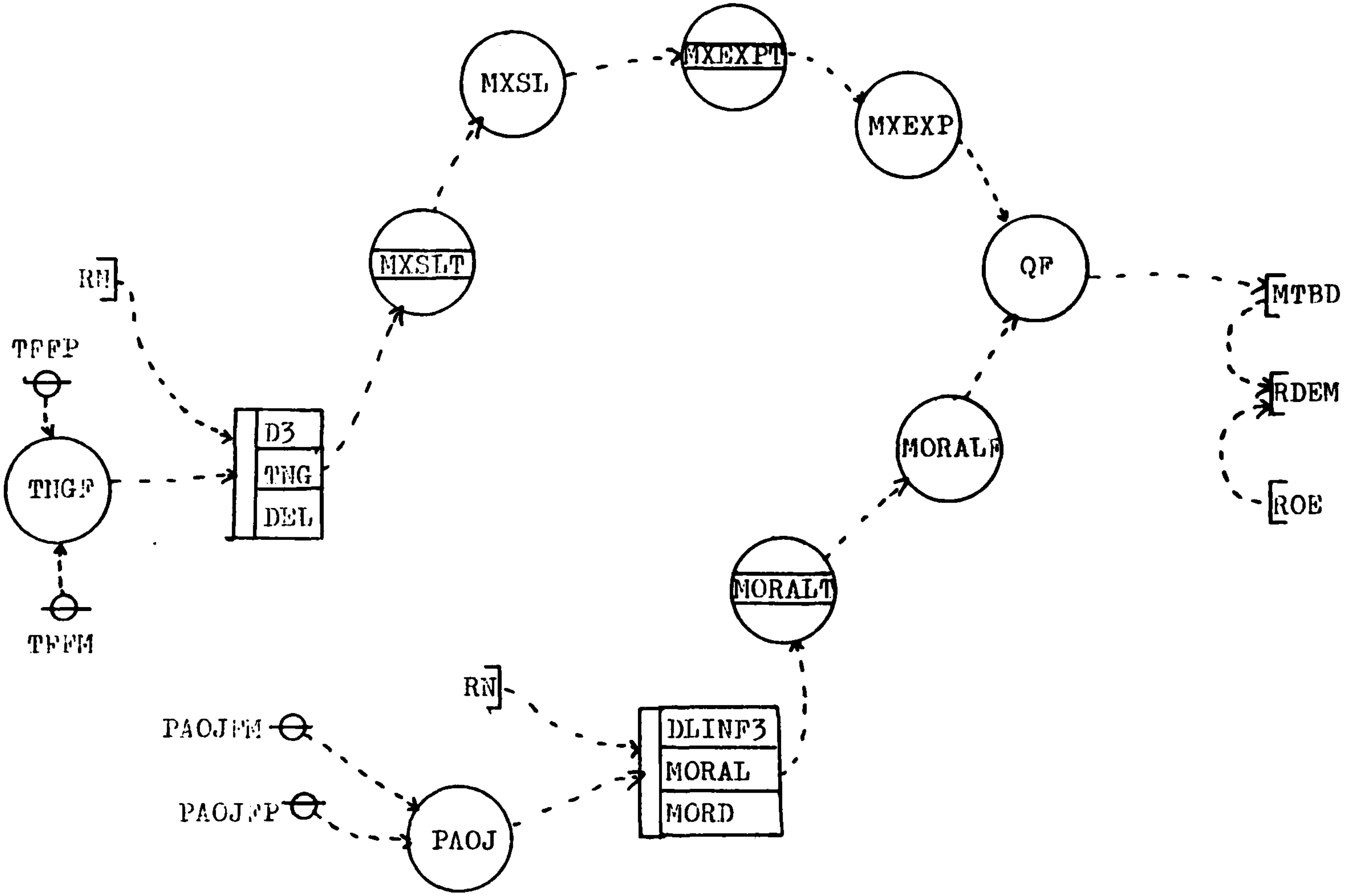
Flow Diagram for the Rate of Demand Generation Sector



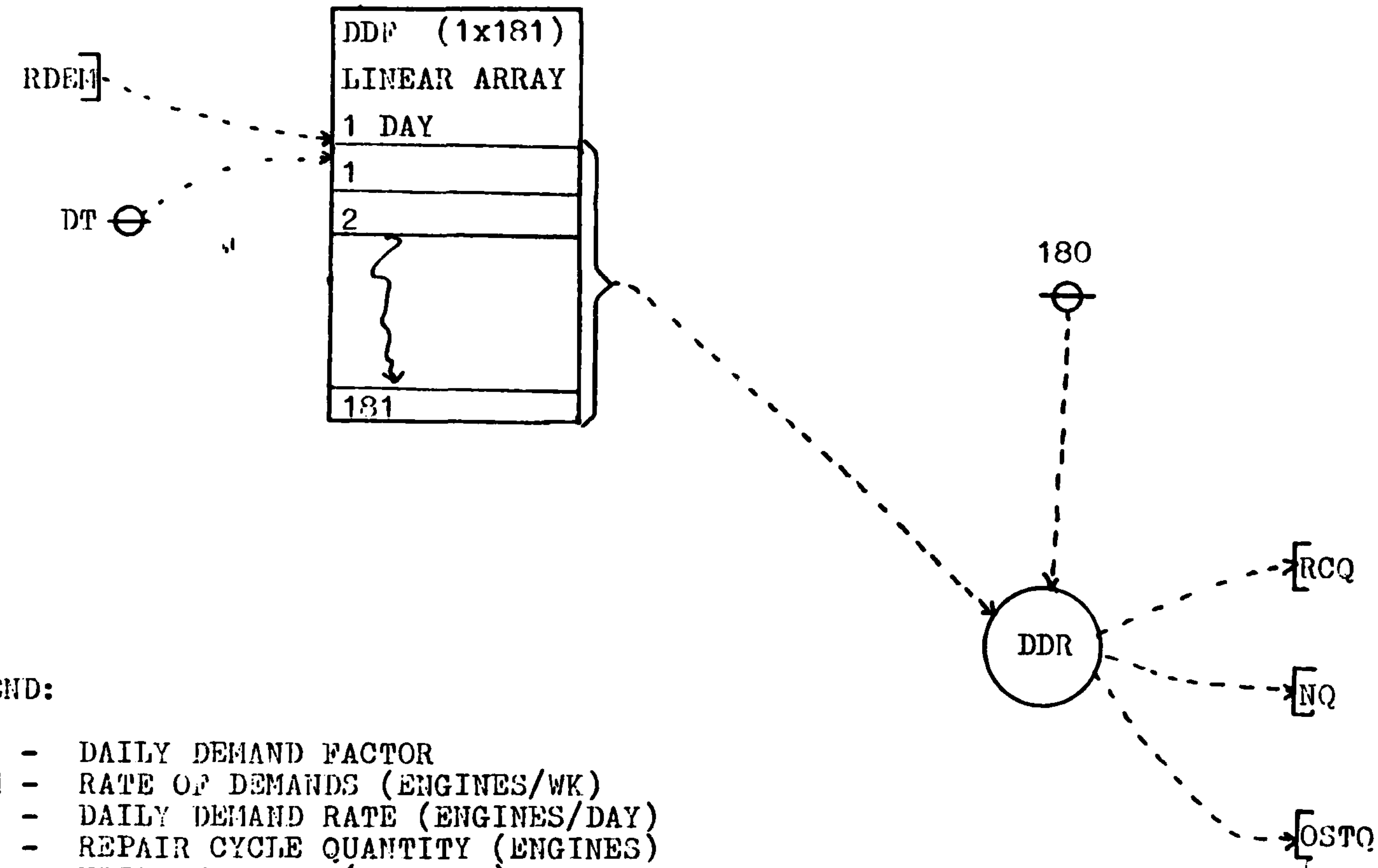
Flow Diagram for Base Engine Repair Process Sector



Flow Diagram of the Compressor Repair Process



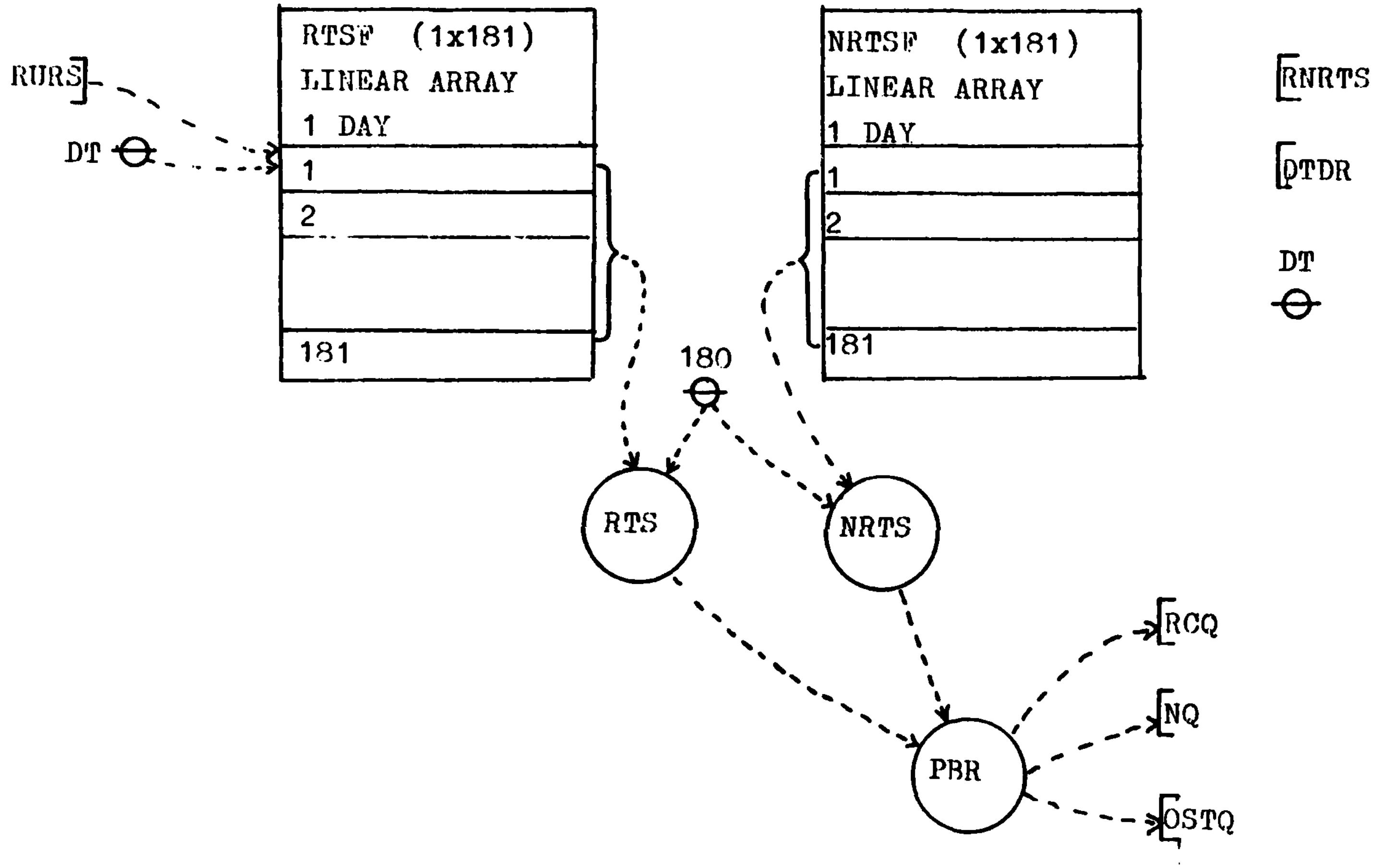
Flow Diagram of the Quality Effects Sector



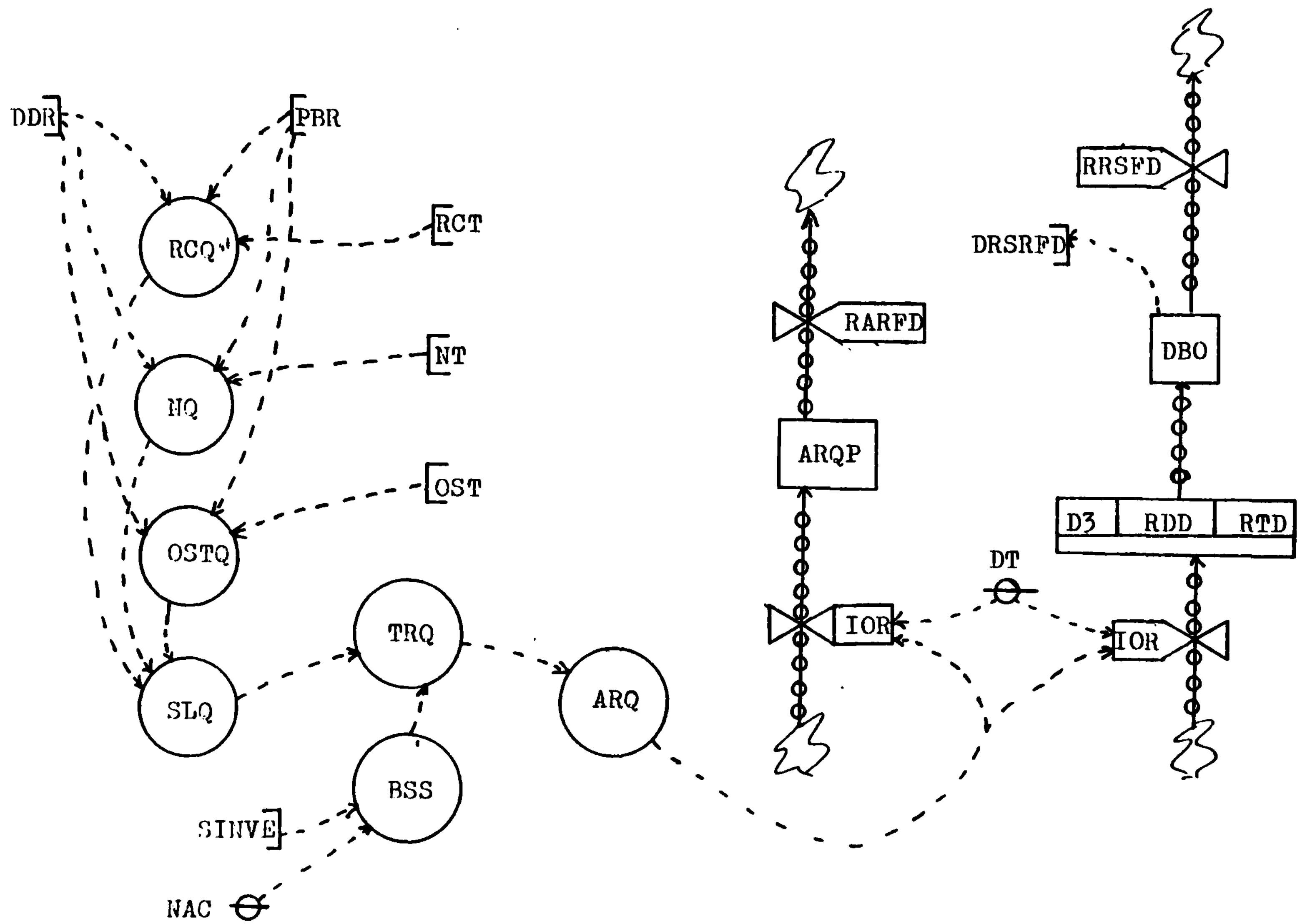
LEGEND:

DDF - DAILY DEMAND FACTOR
RDEM - RATE OF DEMANDS (ENGINES/WK)
DDR - DAILY DEMAND RATE (ENGINES/DAY)
RCQ - REPAIR CYCLE QUANTITY (ENGINES)
NQ - NRTS QUANTITY (ENGINES)
OSTQ - ORDER AND SHIP TIME QUANTITY (ENGINES)

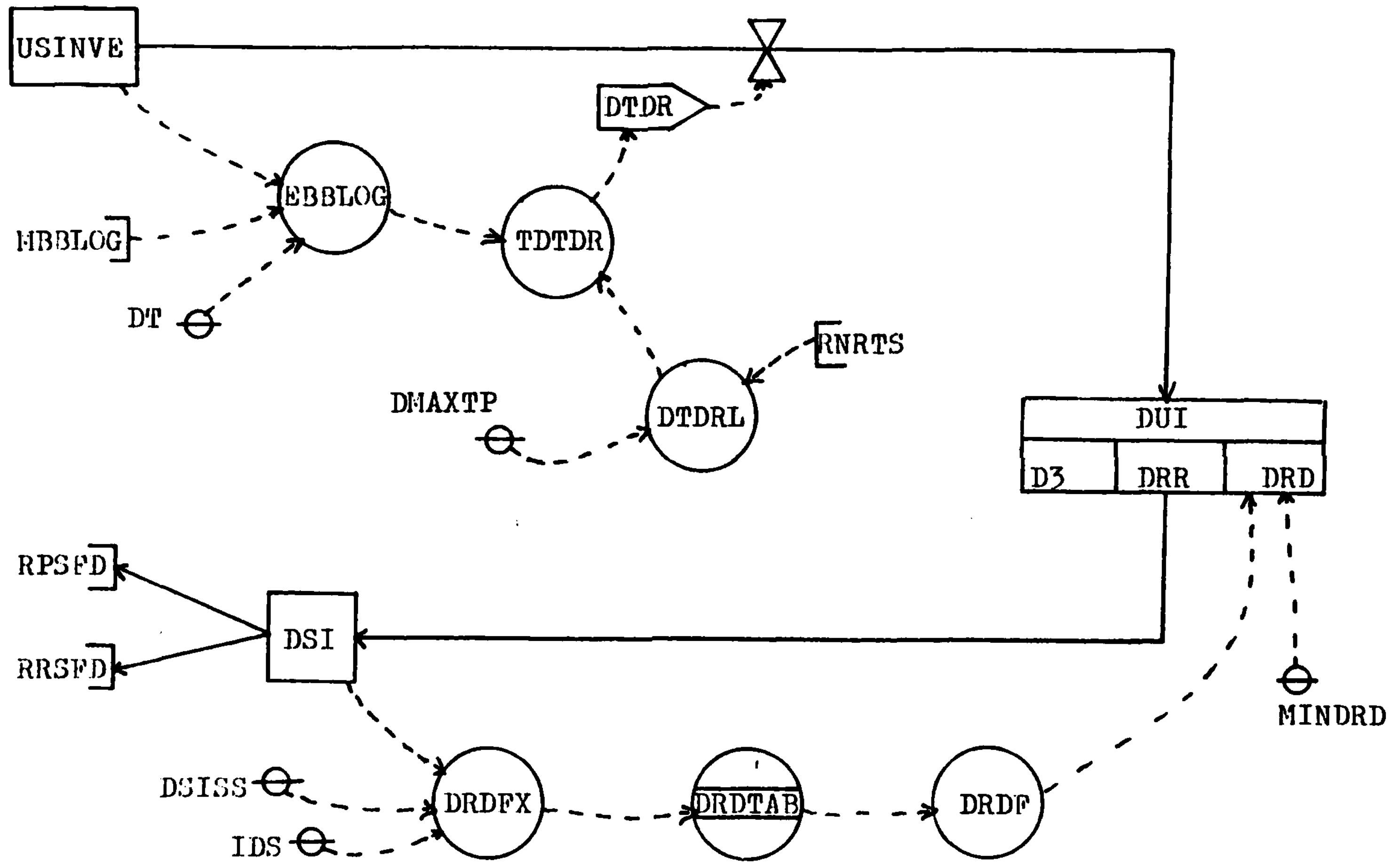
Flow Diagram for the Daily Demand Rate



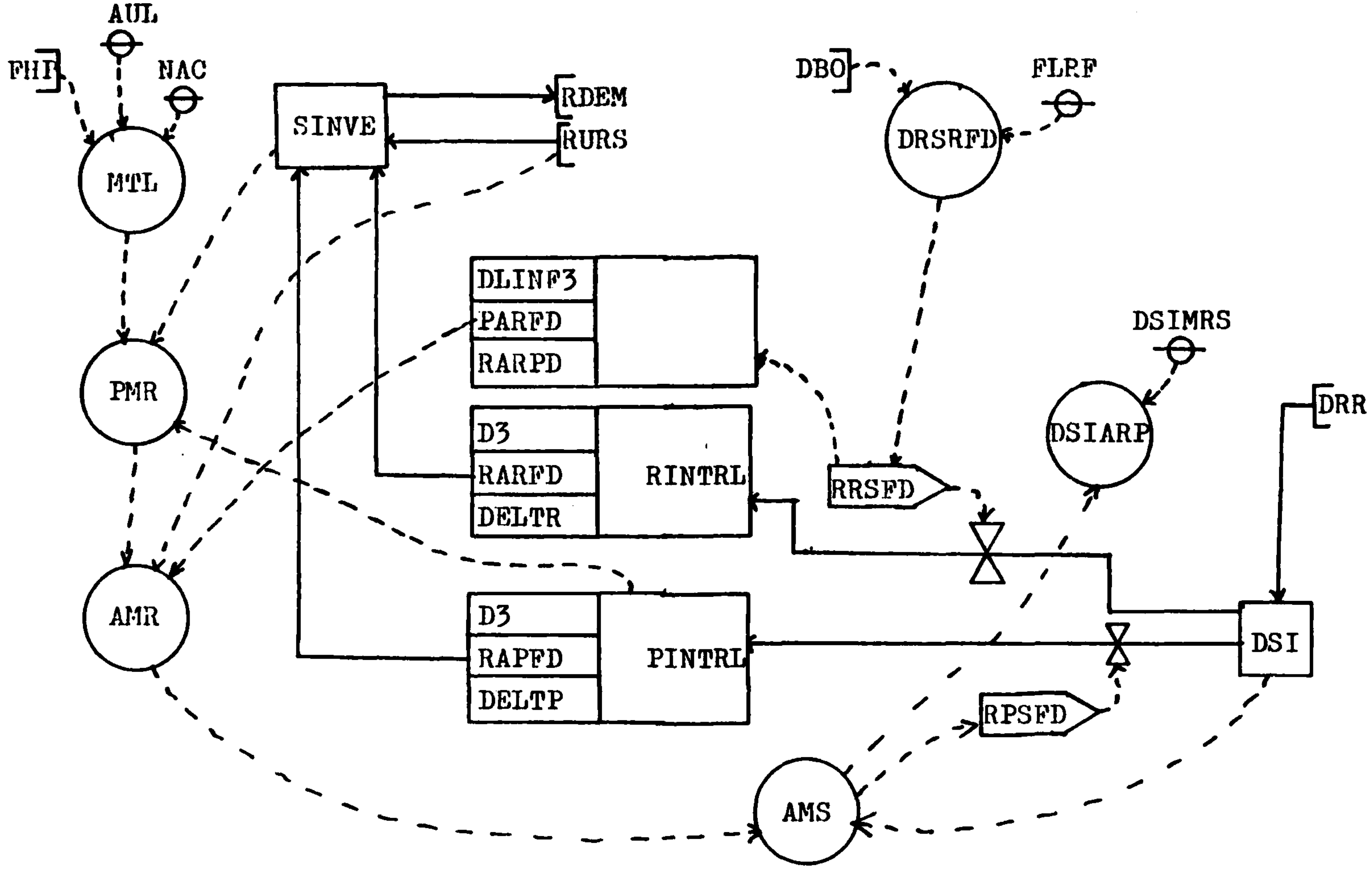
Flow Diagram for the Percentage Base Repair



Flow Diagram for Repair Cycle Quantities, Requisitions and Depot Backorders



Flow Diagram for the Depot Repair Process



Flow Diagram for Depot Resupply Sector

APPENDIX C

DYNAMO SIMULATION PROGRAM LISTING

```
*    ENGINE MANAGEMENT SYSTEM POLICY ANALYSIS MODEL


     DEMAND RATE GENERATION SECTOR

     RATE OF EFFORT DETERMINATION

A     SVCAC.K=MIN((SINVE.K/ECF),NAC)
C     ECF=2
C     NAC=72
A     DAU.K=FHP/SVCAC.K
A     RAUF.K=TABHL(AUFTAB,(DAU.K/AUL),0,1,.1)
T     AUFTAB=.1/.1/.2/.3/.4/.5/.6/.7/.78/.83/.85
C     AUL=25
A     RAU.K=RAUF.K*AUL
A     ROE.K=DLINF3(RAU.K*SVCAC.K,1)
A     MTBDD.K=NORMRN(560,60)
A     RN.K=NOISE()
A     MTBDI.K=TABHL(MTITAB,RN.K,-.5,.5,1)
T     MTITAB=4/12
A     IMTBD.K=SAMPLE(MTBDD.K,MTBDI.K,560)

     MTBD DETERMINATION

A     MTBD.K=QF.K*(SMOOTH(IMTBD.K,MTBDSF))
C     MTBDSF=5

     RDEM DETERMINATION

R     RDEM.KL=ROE.K/MTBD.K

         SCVAC  SERVICEABLE AIRCRAFT (UNITS)
         SINVE - SERVICEABLE INVENTORY OF ENGINES (ENGINES)
         NAC - NUMBER OF AIRCRAFT (UNITS)
         DAU - DESIRED AIRCRAFT UTILIZATION (FLY HR/WK/AIRCRAFT)
         FHP - FLYING HOUR PROGRAM (FLY HR/WK)
         RAUF - REALIZED AIRCRAFT UTILIZATION FACTOR
         AUFTAB - AIRCRAFT UTILIZATION FACTOR TABLE
         AUL - ABSOLUTE UTILIZATION LIMIT (FLY HR/AIRCRAFT/WK)
         RAU - REALIZED AIRCRAFT UTILIZATION (FLY HR/AIRCRAFT/WK)
         ROE - RATE OF EFFORT (FLY HR/WK)
         MTBDD - MTBD DISTRIBUTION (FLY HR)
         RN - RANDOM NUMBER
         MTBDI - MTBD INTERVAL (WKS)
         MTITAB - MEAN TIME INTERVAL TABLE
         IMTBD - INSTANTANEOUS MTBD (FLY HR)
         MTBD - MEAN TIME BETWEEN DEMANDS (FLY HR)
         QF - QUALITY FACTOR
```

```
    MTBDSF - MTBD SMOOTHING FACTOR (WKS)
    RDEM - RATE OF DEMAND (ENGINES/WK)
```

BASE ENGINE & COMPRESSOR REPAIR PROCESS SECTOR

ENGINE REPAIR PROCESS

```
L     USINVE.K=USINVE.J+DT*(RDEM.JK-RUSUR.JK-DTDR.JK)
N     USINVE=0
A     PDR.K=DLINF3(RDEM.JK,UMRD)
C     UMRD=0.2
A     RRF1.K=TABHL(RF1TAB,(PDR.K/MAXTP),0,1,.1)
T     RF1TAB=.5/.5/.53/.58/.65/.73/.82/.91/.97/.98/1.0
A     RRF2.K=TABHL(RF2TAB,RAUF.K,0,.7,.1)
T     RF2TAB=.5/.5/.5/.52/.66/.88/.99/1.0
A     DRUSUR.K=MAX(RRF1.K*MAXTP,RRF2.K*MAXTP)
R     RUSUR.KL=FIFGE(USINVE.K/DT,DRUSUR.K,DRUSUR.K,USINVE.K/DT)
C     MAXTP=2.0
L     URINV1.K=URINV1.J+DT*(RUSUR.JK-RNRTS.JK-EDR.JK)
N     URINV1=0
R     RNRTS.KL=DELAY3(PROPD*RUSUR.JK,DELA)
C     PROPD=0.2
C     DELA=1.1
R     EDR.KL=DELAY3((1-PROPD)*RUSUR.JK,EDD)
C     EDD=0.28
L     URINV2.K=URINV2.J+DT*(EDR.JK-ERR.JK)
N     URINV2=0
A     RRF3X.K=EDR.JK/((1-PROPD)*MAXTP)
A     RRF3.K=TABHL(RF3TAB,RRF3X.K,0,1,.1)
T     RF3TAB=.625/.625/.635/.66/.71/.77/.83/.88/.95/.99/1.0

     THE MINIMUM VALUE OF THE ABOVE TABLE IS RELATED TO
        THE MINIMUM VALUE OF THE TABLE FOR RRF1 AS FOLLOWS
          .625=RRF1(MIN)/(1-PROPD)

A     DERR.K=RRF3.K*(1-PROPD)*MAXTP
A     TERR.K=FIFGE(URINV2.K/DT,DERR.K,DERR.K,URINV2.K/DT)
A     CPCRL.K=BSCPI.K/DT
A     ERRL.K=FIFGE(CPCRL.K/CPGF,TERR.K,TERR.K,CPCRL.K/CPGF)
R     ERR.KL=ERRL.K
N     ERR=0
L     URINV3.K=URINV3.J+DT*(ERR.JK-RURS.JK)
N     URINV3=0
R     RURS.KL=DELAY3(ERR.JK,ERD)
C     ERD=2
L     SINVE.K=SINVE.J+DT*(RURS.JK+RARFD.JK+RAPFD.JK-RDEM.JK)
N     SINVE=BE
C     BE=151
```

USINVE - UNSERVICEABLE ENGINE INVENTORY (ENGINES)
RDEM - RATE OF DEMAND (ENGINES/WK)
DTDR - DIVERSION TO DEPOT RATE (ENGINES/WK)
PDR - PERCEIVED DEMAND RATE (ENGINES/WK)
UMRD - UNIT MAINTENANCE RESPONSE DELAY (WKS)
RRF1 - REPAIR RATE FACTOR 1
RF1TAB - REPAIR RATE FACTOR 1 TABLE
RRF2 - REPAIR RATE FACTOR 2
RF2TAB - REPAIR RATE FACTOR 2 TABLE
RAUF - REALIZED AIRCRAFT UTILIZATION FACTOR
DRUSUR - DESIRED RATE UNSERVICEABLES GO UNDER REPAIR (ENGINES/WK)
RUSUR - RATE UNSERVICEABLES GO UNDER REPAIR (ENGINES/WK)
MAXTP - MAXIMUM THROUGHPUT (ENGINES/WK)
URINV1 - UNDER REPAIR INVENTORY 1 (ENGINES)
RNRTS - RATE ENGINES DECLARED NRTS (ENGINES/WK)
PROPD - PROPORTION OF ENGINES TO DEPOT
DELA - DELAY FOR NRTS ASSESSMENT (WKS)
EDR - ENGINE DIAGNOSIS RATE (ENGINES/WK)
EDD - ENGINE DIAGNOSIS DELAY (WKS)
URINV2 - UNDER REPAIR INVENTORY 2 (ENGINES AWAITING COMPRESSORS)
RRF3X - REPAIR RATE FACTOR 3 INDEX
RRF3 - REPAIR RATE FACTOR 3
RF3TAB - REPAIR RATE FACTOR 3 TABLE
DERR - DESIRED ENGINE REPAIR RATE (ENGINES/WK)
TERR - TRIAL ENGINE REPAIR RATE (ENGINES/WK)
CPCRL - COMPRESSOR CONSUMPTION RATE LIMIT (COMPRESSORS/WK)
ERRL - ENGINE REPAIR RATE LIMIT (ENGINES/WK)
ERR - ENGINE REPAIR RATE (ENGINES/WK)
URINV3 - UNDER REPAIR INVENTORY 3 (ENGINES)
RURS - RATE AT WHICH UNSERVICEABLES RETURN TO SERVICE (ENGINES/WK)
ERD - ENGINE REPAIR DELAY (WKS)
SINVE - SERVICEABLE INVENTORY OF ENGINES (ENGINES)
(ENGINES/WK)
(ENGINES/WK)
BE - BASE ENGINE INVENTORY (ENGINES)

QUALITY EFFECTS SECTOR

```
A     QF.K=MXEXP.K*MORALF.K
A     MXEXP.K=TABLE(MXEXPT,MXSL.K,0,1,.1)
T     MXEXPT=0/.14/.27/.40/.51/.62/.74/.81/.89/.94/.98
A     MXSL.K=TABLE(MXSLT,TNG.K,0,1,.1)
T     MXSLT=0/.3/.58/.72/.8/.88/.9/.94/.96/.97/.98
A     TNG.K=DELAY3(RN.K+TNGF.K,DEL)
A     TNGF.K=.5+TFFM*SIN(6.28*TIME.K/TFFP)
C     DEL=8
C     TFFP=78
C     TFFM=.25
A     MORALF.K=TABLE(MORALT,MORAL.K,0,2,.2)
T     MORALT=1/1/1/1/1/1/1/.99/.95/.80/.0001
A    MORAL.K=DLINF3((PAOJ.K+RN.K),MORD)
C     MORD=2.5
A    PAOJ.K=1+PAOJFM*(SIN((6.28*TIME.K)/PAOJFP))
C     PAOJFM=.75
C     PAOJFP=40
```

QF - QUALITY FACTOR
MXEXP - MAINTENANCE EXPERIENCE
MXEXPT - MAINTENANCE EXPERIENCE TABLE
MXSL - MAINTENANCE SKILL LEVEL
MXSLT - MAINTENANCE SKILL LEVEL TABLE
TNG - TRAINING
TNGF - TRAINING FACTOR
DEL - TRAINING DELAY
TFFP - TRAINING FACTOR FREQUENCY PERIOD
TFFM - TRAINING FACTOR FREQUENCY MODULATION
MORALF - MORALE FACTOR
MORALT - MORALE FACOTR TABLE
MORAL - MORALE
PAOJ - PERCEIVED AVAILABILITY OF OUTSIDE JOBS
MORD - MORALE DELAY
PAOJFM - PERCEIVED AVAILABILITY OF OUTSIDE JOBS
FREQUENCY MODULATION
PAOJFP - PERCEIVED AVAILABILITY OF OUTSIDE JOBS
FREQUENCY PERIOD

COMPRESSOR REPAIR PROCESS

```
R     RCPR.KL=EDR.JK*CPGF
C     CPGF=.40
L     USCPI.K=USCPI.J+DT*(RCPR.JK-RCPUR.JK)
N     USCPI=0
A     CPRFX.K=RCPR.JK/MTPCP
C     MTPCP=5
A     DCPRF.K=TABHL(CPRFT,CPRFX.K,0,1,.1)
T     CPRFT=.5/.5/.53/.58/.65/.73/.82/.91/.97/.98/1.0
A     CPRRF.K=FIFZE(DCPRF.K,1,TERR.K-ERRL.K)
R     RCPUR.KL=FIFGE(USCPI.K/DT,CPRRF.K*MTPCP,CPRRF.K*MTPCP,
X        USCPI.K/DT)
L     BUCPI.K=BUCPI.J+DT*(RCPUR.JK-BCPRR.JK-NCPR.JK)
N     BUCPI=0
R     NCPR.KL=DELAY3(PCPD*RCPUR.JK,NCPD)
C     PCPD=0.9
C     NCPD=0.5
L     DCPI.K=DCPI.J+DT*(NCPR.JK-DCPRR.JK)
N     DCPI=0
R     DCPRR.KL=DELAY3(NCPR.JK,DCPRD)
C     DCPRD=6
R     BCPRR.KL=DELAY3((1-PCPD)*RCPUR.JK,BCPRD)
C     BCPRD=2
L     BSCPI.K=BSCPI.J+DT*(BCPRR.JK+DCPRR.JK-CPCR.JK)
N     BSCPI=BCP
C     BCP=5
R     CPCR.KL=ERRL.K*CPGF
```

RCPR - REPAIRABLE COMPRESSOR RATE (COMPRESSOR/WK)
CPGF - COMPRESSOR GENERATION FACTOR (COMPRESSORS/ENGINE)
USCPI - UNSERVICEABLE COMPRESSOR INVENTORY (COMPRESSORS)
CPRFX - COMPRESSOR REPAIR FACTOR INDEX
MTPCP - MAXIMUM THROUGHPUT OF COMPRESSORS (COMPRESSORS/WK)
DCPRF - DESIRED COMPRESSOR REPAIR FACTOR
CPRFT - COMPRESSOR REPAIR FACTOR TABLE
CPRRF - COMPRESSOR REPAIR RATE FACTOR
RCPUR - RATE COMPRESSORS GO UNDER REPAIR (COMPRESSORS/WK)
BUCPI - BASE UNSERVICEABLE COMPRESSOR INVENTORY (COMPRESSORS)
NCPR - RATE COMPRESSORS DECLARED NRTS (COMPRESSORS/WK)
PCPD - PROPORTION OF COMPRESSORS TO DEPOT
NCPD - NRTS COMPRESSOR ASSESSMENT DELAY (WKS)
DCPI - DEPOT COMPRESSOR INVENTORY (COMPRESSORS)
DCPRR - DEPOT COMPRESSOR REPAIR RATE (COMPRESSORS/WK)
DCPRD - DEPOT COMPRESSOR REPAIR DELAY (WKS)
BCPRR - BASE COMPRESSOR REPAIR RATE (COMPRESSORS/WK)
BCPRD - BASE COMPRESSOR REPAIR DELAY (WKS)
BSCPI - BASE SERVICEABLE COMPRESSOR INVENTORY (COMPRESSORS)
BCP - BASE COMPRESSOR STOCK (COMPRESSORS)
CPCR - COMPRESSOR CONSUMPTION RATE (COMPRESSORS/WK)

```
     ROUTINE REQUISITION PROCESS SECTOR

     ENGINE DAILY DEMAND RATE COMPUTATION

FOR   I=1,181
L     DDF.K(1)=DDF.J(1)+DT*RDEM.JK
N     DDF(I)=0.02
A     DDR.K=SUMV(DDF.K,2,181)/180
S     LDD.K=SHIFTL(DDF.K,.143)

         DDF - DAILY DEMAND FACTOR
         RDEM - RATE OF DEMAND (ENGINES/WK)
         DDR - DAILY DEMAND RATE (ENGINES/DAY)
         LDD - DAILY DEMAND FACTOR ARRAY SHIFT DUMMY VARIABLE

     BASE REPAIR RATE COMPUTATION

L     RTSF.K(1)=RTSF.J(1)+DT*RURS.JK
N     RTSF(I)=0.8
A     RTS.K=SUMV(RTSF.K,2,181)/180
S     LRTS.K=SHIFTL(RTSF.K,.143)
L     NRTSF.K(1)=NRTSF.J(1)+(DT*(RNRTS.JK+DTDR.JK))
N     NRTSF(I)=0.2
A     NRTS.K=SUMV(NRTSF.K,2,181)/180
S     LNRTS.K=SHIFTL(NRTSF.K,.143)
A     PBR.K=RTS.K/(RTS.K+NRTS.K)

         RTSF - REPARABLE THIS STATION FACTOR
         RURS - RATE AT WHICH UNSERVICEABLES RETURN TO SERVICE
        (ENGINES/WK)
         RTS - REPARABLE THIS STATION (ENGINES/DAY)
         LRTS - RTS FACTOR ARRAY SHIFT DUMMY VARIABLE
         NRTSF - NOT REPARABLE THIS STATION FACTOR
         RNRTS - RATE ENGINES DECLARED NRTS (ENGINES/WK)
         DTDR - DIVERSION TO DEPOT RATE (ENGINES/WK)
         NRTS - NOT REPARABLE THIS STATION (ENGINES/DAY)
         LNRTS - NRTS FACTOR ARRAY SHIFT DUMMY VARIABLE
         PBR - PERCENTAGE BASE REPAIR

     REPAIR CYCLE QUANTITIES

A     RCQ.K=(DDR.K*PBR.K*RCT)
C     RCT=14               - IN DAYS
A     NQ.K=DDR.K*(1-PBR.K)*NT
C     NT=8               - IN DAYS
A     OSTQ.K=DDR.K*(1-PBR.K)*OST
C     OST=6.0              - IN DAYS
A     SLQ.K=SQRT(3*(RCQ.K+NQ.K+OSTQ.K))*CFACT
C     CFACT=2.0
```

RCQ - REPAIR CYCLE QUANTITY (ENGINES)
DDR - DAILY DEMAND RATE (ENGINES/DAY)
PBR - PERCENTAGE BASE REPAIR
RCT - REPAIR CYCLE TIME (DAYS)
NQ - NRTS QUANTITY (ENGINES)
NT - NRTS ASSESSMENT TIME (DAYS)
OSTQ - ORDER AND SHIP TIME QUANTITY (ENGINES)
OST - ORDER AND SHIP TIME (DAYS)
SLQ - SAFETY LEVEL QUANTITY (ENGINES)
CFACT - C-FACTOR

ORDER COMPUTATION

```
A      BSS.K=MAX(0,(SINVE.K-NAC*ECF))
A      TRQ.K=MAX(0,(SLQ.K-BSS.K))
L      ARQP.K=ARQP.J+DT*(IOR.JK-RARFD.JK)
N      ARQP=0
A      ARQ.K=MAX(0,(TRQ.K-ARQP.K))
R      IOR.KL=ARQ.K/DT
```

BSS - BASE SERVICEABLE STOCK (ENGINES)
SINVE - SERVICEABLE INVENTORY OF ENGINES (ENGINES)
NAC - NUMBER OF AIRCRAFT (UNITS)
TRQ - TRIAL REQUISITION QUANTITY (ENGINES)
SLQ - SAFETY LEVEL QUANTITY (ENGINES)
ARQP - ACTUAL REQUISITIONS PLACED WITH DEPOT (ORDERS)
RARFD - RATE OF ARRIVAL OF ROUTINE SHIPMENTS FROM DEPOT (ENGINES/WK)
ARQ - ACTUAL REQUISITION QUANTITY (ENGINES)
IOR - INSTANTANEOUS ORDER RATE (ENGINE ORDERS/WK)

BACKORDER ACCUMULATION

```
R      RDD.KL=DELAY3(IOR.JK,RTD)
C      RTD=.1
L      DBO.K=DBO.J+DT*(RDD.JK-RRSFD.JK)
N      DBO=0
```

RDD - REQUISITION DELAY TO DEPOT (ORDERS/WK)
IOR - INSTANTANEOUS ORDER RATE (ENGINE ORDERS/WK)
RTD - REQUISITION TRANSMISSION DELAY (WKS)
DBO - DEPOT BACK ORDERS (ORDERS)
RRSFD - RATE OF ROUTINE SHIPMENTS FROM DEPOT (ENGINES/WK)

DEPOT REPAIR SECTOR

```
A     EBBLOG.K=MAX(USINVE.K-MBBLOG,0)
C     MBBLOG=2     (MAXTP*AVG DEPOT TAT OF 6.5 WKS)
A     TDTDR.K=EBBLOG.K/DT
A     DTDRL.K=DMAXTP-RNRTS.JK
C     DMAXTP=.4       (2*PROPD*MAXTP)
R     DTDR.KL=FIFGE(DTDRL.K,TDTDR.K,TDTDR.K,DTDRL.K)
L     DUI.K=DUI.J+DT*(RNRTS.JK+DTDR.JK-DRR.JK)
N     DUI=0
R     DRR.KL=DELAY3((RNRTS.JK+DTDR.JK),DRD.K)
A     DRDFX.K=DSI.K/DSISS
A     DRDF.K=TABHL(DRDTAB,DRDFX.K,1.1,IDS/DSISS,(IDS/DSISS)-1.1)
T     DRDTAB=1/2.75
C     IDS=10
C     DSISS=2       (2*DSIMRS)
A     DRD.K=DRDF.K*MINDRD
C     MINDRD=3.5
L     DSI.K=DSI.J+DT*(DRR.JK-RRSFD.JK-RPSFD.JK)
N     DSI=IDS
```

EBBLOG - EXCESS BASE MAINTENANCE BACKLOG (ENGINES)
USINVE - UNSERVICEABLE ENGINE INVENTORY (ENGINES)
MBBLOG - MAXIMUM BASE MAINTENANCE BACKLOG (ENGINES)
TDTDR - TRIAL DIVERSION TO DEPOT RATE (ENGINES/WK)
DTDRL - DIVERSION TO DEPOT RATE LIMIT (ENGINES/WK)
DMAXTP - DEPOT MAXIMUM REPAIR THROUGHPUT (ENGINES/WK)
RNRTS - RATE ENGINES DECLARED NRTS (ENGINES/WK)
DTDR - DIVERSION TO DEPOT RATE (ENGINES/WK)
DUI - DEPOT UNSERVICEABLE INVENTORY (ENGINES)
DRR - DEPOT REPAIR RATE (ENGINES/WK)
DRDFX - DEPOT REPAIR DELAY FACTOR INDEX
DRDF - DEPOT REPAIR DELAY FACTOR
DRDTAB - DEPOT REPAIR DELAY TABLE
IDS - INITIAL DEPOT STOCK (ENGINES)
DSISS - DEPOT SERVICEABLE INVENTORY SAFETY STOCK (ENGINES)
DRD - DEPOT REPAIR DELAY (WKS)
MINDRD - MINIMUM DEPOT REPAIR DEALY (WKS)
DSI - DEPOT SERVICEABLE INVENTORY (ENGINES)
RRSFD - RATE OF ROUTINE SHIPMENTS FROM DEPOT (ENGINES/WK)
RPSFD - RATE OF PRIORITY SHIPMENTS FROM DEPOT (ENGINES/WK)

DEPOT RESUPPLY SECTOR

MICAP DETERMINATION AND DEPOT RESPONSE

```
A      MTL.K=MIN(FHP/(0.7*AUL),NAC)
A      PMR.K=MAX((MTL.K-(PINTRL.K+SINVE.K)),0)
A      PARFD.K=DLINF3(RRSFD.JK,RARPD)
C      RARPD=1.5
A      AMR.K=MAX((PMR.K-RURS.JK*DELTP-PARFD.K*DELTP),0)
N      AMR=0
A      AMS.K=MIN(AMR.K,DSI.K)
R      RPSFD.KL=AMS.K/DT
L      PINTRL.K=PINTRL.J+DT*(RPSFD.JK-RAPFD.JK)
N      PINTRL=0
R      RAPFD.KL=DELAY3(RPSFD.JK,DELTP)
C     DELTP=1.0
```

MTL - MICAP THRESHOLD LEVE (ENGINES)
FHP - FLYING HOUR PROGRAM (FLY HR/WK)
AUL - ABSOLUTE UTILIZATION LIMIT (FLY HR/AIRCRAFT/WK)
ECF - ENGINE CORRECTION FACTOR (ENGS/AIRCRAFT)
NAC - NUMBER OF AIRCRAFT (UNITS)
PMR - POTENTIAL MICAP REQUIREMENTS (ENGINES)
SINVE - SERVICEABLE INVENTORY OF ENGINES (ENGINES)
PARFD - PERCEIVED ARRIVAL RATE ROUTINE SHIPMENTS FROM DEPOT (ENGINES/WK)
RRSFD - RATE OF ROUTINE SHIPMENTS FROM DEPOT (ENGINES/WK)
RARPD - ROUTINE ARRIVAL RATE PERCEPTION DELAY (WKS)
AMR - ACTUAL MICAP REQUIREMENTS (ENGINES)
RURS - RATE AT WHICH UNSERVICEABLES RETURN TO SERVICE (ENGINES/WK)
AMS - ACTUAL MICAP SHIPMENTS (ENGINES)
DSI - DEPOT SERVICEABLE INVENTORY (ENGINES)
RPSFD - RATE OF PRIORITY SHIPMENTS FROM DEPOT (ENGINES/WK)
PINTRL - PRIORITY SHIPMENTS INTRANSIT LEVEL (ENGINES)
RAPFD - RATE OF ARRIVAL OF PRIORITY SHIPMENTS FROM DEPOT (ENGINES/WK)
DELTP - PRIORITY TRANSPORTATION PIPELINE DELAY (WKS)

ROUTINE REQUISITIONS RESPONSE

```
A      DSIARP.K=MAX((DSI.K-DSIMRS-AMS.K),0)
C      DSIMRS=1
A      DRSRFD.K=DBO.K/FLRF
C      FLRF=0.4
R      RRSFD.KL=FIFGE(DSIARP.K/DT,DRSRFD.K,DRSRFD.K,DSIARP.K/DT)
L      RINTRL.K=RINTRL.J+DT*(RRSFD.JK-RARFD.JK)
N      RINTRL=0
R      RARFD.KL=DELAY3(RRSFD.JK,DELTR)
C     DELTR=1.0
C
```

DSIARP - DEPOT SERVICEABLE INVENTORY AVAILABLE TO THE ROUTINE PIPELINE (ENGINES)

DSI - DEPOT SERVICEABLE INVENTORY (ENGINES)
AMS - ACTUAL MICAP SHIPMENTS (ENGINES)
DSIMRS - DEPOT SERVICEABLE INVENTORY MICAP RESERVE STOCK (ENGINES)
DRSRFD - DESIRED ROUTINE SHIPMENT RATE FROM DEPOT (ENGINES/WK)
DBO - DEPOT BACK ORDERS (ORDERS)
FLRF - FILL RATE FACTOR (WKS)
RRSFD - RATE OF ROUTINE SHIPMENTS FROM DEPOT (ENGINES/WK)
RINTRL - ROUTINE INTRANSIT PIPELINE LEVEL (ENGINES)
RARFD - RATE OF ARRIVAL OF ROUTINE SHIPMENTS FROM DEPOT (ENGINES/WK)
DELTR - ROUTINE TRANSPORTATION DELAY (WKS)

SUPPLEMENTARIES

```
S     ATBA.K=SINVE.K+USINVE.K+URINV1.K+URINV2.K+URINV3.K+
X        RINTRL.K+PINTRL.K
S     PTBA.K=(NAC*ECF)+BSS.K+RCQ.K+NQ.K+OSTQ.K+ARQP.K+PINTRL.K
S     PWDR.K=DDR.K*7
S     TRTD.K=(RNRTS.JK+DTDR.JK)
S     BMXW.K=USINVE.K+URINV1+URINV2+URINV3
```

ATBA - ACTUAL TOTAL BASE ASSETS (ENGINES)
PTBA - PERCEIVED TOTAL BASE ASSETS (ENGINES)
PWDR - PERCEIVED WEEKLY DEMAND RATE (ENGINES/WK)
TRTD - TOTAL RATE AT WHICH UNSERVICEABLES ARE SENT TO DEPOT (ENGINES/WK)
BMXW - BASE MAINTENANCE WORKLOAD (ENGINES)

```
A      FHP.K=300+STEP(100,53)-STEP(150,105)+STEP(100,157)
     DIRECTIONS
PRINT 1)USINVE,URINV1,URINV2,URINV3,SINVE,USCPI,BUCPI,DCPI,BSCPI,ARQP/
X      2)DBO,DUI,DSI,PINTRL,RINTRL/
X      3)RDEM,RUSUR,RNRTS,EDR,ERR,RURS,RCPR,RCPUR,NCPR,DCPRR,BCPRR/
X      4)CPCR,IOR,RDD,DTDR,DRR,RPSFD,RAPFD,RRSFD,RARFD/
X      5)SVCAC,ROE,MTBD,PDR,RRF1,RRF2,DRUSUR,RRF3X,RRF3,DERR,TERR/
X      6)CPCRL,ERRL,CPRFX,DCPRF,CPRRF,QF,DDR,RTS,NRTS,PBR,RCQ,NQ,OSTQ/
X      7)SLQ,BSS,TRQ,ARQ,EBBLOG,TDTDR,DTDRL,DRDFX,DRDF,DRD,MTL,PMR,FHP/
X      8)PARFD,AMR,AMS,DSIARP,DRSRFD/
X      9)ATBA,PTBA,PWDR,TRTD,BMXW/
PLOT  USINVE/SINVE/DCPI/BSCPI/DSI/RDEM/RNRTS/NCPR/DTDR/FHP
PLOT  USINVE/SINVE/DUI/USCPI/DBO/RUSUR/EDR/ERR/SVCAC/FHP
PLOT  PINTRL/RINTRL/RPSFD/RAPFD/RRSFD/RARFD/SVCAC/RRF3X/RRF3/QF
PLOT  ARQP/RDEM/EDR/ERR/RCPR/RCPUR/DCPRR/BCPRR/CPCR
PLOT  PBR/RCQ/NQ/OSTQ/DRDF/DRD/DRDFX/BSS/SLQ
PLOT  ATBA/PTBA/PWDR/TRTD/BMXW

SPEC   DT=.05/LENGTH=200/PLTPER=1/PRTPER=1

RUN
..
```

APPENDIX D

RESULTS FOR EXPERIMENTAL RUN 1

```
FHP=1  SINVE=2  NRTS=3  NCPR=4  USINVE=5  DSI=6  RINTRL=7
BSCPI=8  DCPI=9

250.000          300.000          350.000          400.000          450.000  1
146.000          147.500          149.000          150.500          152.000  2
  0.000             .100             .200             .300             .400  34
  0.000            5.000           10.000           15.000           20.000  56
  0.000             .100             .200             .300             .400  7
  0.000            2.000            4.000            6.000            8.000  89
  0.04 - - - - - - - -1- - - - - - - - 3 - - - 8 - - -.- - 2 - - - - . 4579,36
     5             1            36     4  2      .              . 579,48
     5  9          1           3 2  8             . 4           . 26,57
     5    9        1         23  68            4 .              . 57
     5     9       1         23   6      4       .              . 57,68
     5       9     1         32  864             .              . 57
     5       9     1        32  8 4              .              . 46,57
     5        9    1       3 2  846              .              . 57
     5        9    1      3 2   84.6             .              . 57
     5        9    1     3 2    84.6             .              . 57
 10.05 - - - -9- - -1- - 32- - - 8 46- - - - - - - -.- - - - - - - - . 57
     5        9    1   2       8  .4             .              . 23,46,57
     5        9    1  2        8  .46            .              . 23,57
     5        9    123         8  .46            .              . 57
     5        9    13          8  4 6            .              . 12,57
     5    7   9   21           8  4  6           .              . 13
     5        9  231      7    8 4. 6            .              .
     5        9  3 21      7   48 . 6            .              .
     5        9 3  1     7   4 8 . 6             .              . 12
     5        93   1      7  4 8 . 6             .              . 12
 20.05 - - - 93- - -12 - - 7 -4- 8 . 6 - - - - - - -.- - - - - - - - .
     5       3     12       74  8 . 6            .              . 39
     5      39     12        4   8. 6            .              . 47
     5     3 9     1 2      74   8. 6            .              .
     5    3  9     1 2       4   8. 6            .              . 47
     5   3   9     1  2     74   8. 6            .              .
     5  3    9     1   2  7 4    8. 6            .              .
     5  3    9  7  1   2    4    8. 6            .              .
     5  3   79     1   2    4    8. 6            .              .
     5  3   9  7   1  2      4   8. 6            .              .
 30.05 -3- -9- - - -1-2- - - -4- -8. 6 - - - - - - -.- - - - - - - - . 17
     5  3   9      1 27      4   8. 6            .              .
     5  3    9     1 2  7    4   8. 6            .              .
     5  3    9     1 2 7     4   8. 6            .              .
     5  3    9     1 2       4   8. 6            .              . 27
     5  3    9     1 2       4   8. 6            .              . 17
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      5  3    9      1 2      4   8. 6               .               . 17
      5  3    9      1 2      4   8.  6              .               . 17
      5  3    9      12        4  8.  6              .               . 27
      5  3    9      127       4  8.  6              .               .
40.05 -3- - 9 - - -127- - - - 4 -8. -6- - - - - - - -.- - - - - - - -.
      5  3    9      12 7      4  8.  6              .               .
      5  3    9      12   7     4 8.  6              .               .
      5  3    9      1      7   4 8. 6               .               . 12
      5  3    9      1       7    48. 6              .               . 12
      5  3    9      1       7    4 . 6              .               . 12,48
      5  3    9      12      7    4 . 6              .               . 48
      5  3    9      12     7     84. 6              .               .
      5  3    9      12      7    84. 6              .               .
      5  3    9      1           78 4 6              .               . 12
50.05 -3- - -9- - -1- - - - - - 8 .64 - - - - - - - -.- - - - - - - -. 12,67
      5  3     9     1            8 .64              .               . 12,67
      5  3     9     12          8  .6 4             .               . 67
      5  3     9     .2          8  .6 4             1               . 67
      5  3     9     2           8  6    4           1               . 47
      5  3       9  2.          8   6           4    1       7       .
      5  3       9   2          8   6.           4   1            7  .
      5  3        9   . 2      8    6.         4  71                 .
      5  3        9   .   2    8 7  6.      4        1               .
      5  3        9   .   27   8    6.    4          1               .
60.05 -3- - - -9- -.- -2-7- -8- -6. - - 4 - - - - -1- - - - - - - -.
      5  3        9   .   2   78    6.    4          1               .
      5  3        9   .   2    8  76.     4          1               .
      5  3        9   .   2    8  6 . 7    4         1               .
      5  3        9   .   2    8  6 .    7  4        1               .
      5  3        9   .   2    8  6 .     7  4       1               .
      5  3        9   .    2   8  6 .     7  4       1               .
      5  3        9   .    2   8  6 .  7     4       1               .
      5  3        9   .     2  8  6 .7      4        1               .
      5  3        9   .     2  8  67.       4        1               .
70.05 - 3 - - -9- -.- - - 2 -8-76 . - - -4- - - -1- - - - - - - -.
      5   3       9   .      2  87 6 .      4        1               .
      5   3       9   .      2  87 6 .      4        1               .
      5   3       9   .      2 7   6 .     4         1               . 78
      5   3       9   .      278   6 .     4         1               .
      5   3       9   .      2 8   6 .    4          1               . 27
      5   3       9   .      2 8   6 .    4          1               . 27
      5   3       9   .      278   6 .    4          1               .
      5   3       9   .      2 87  6 .    4          1               .
      5   3       9   .      2  7  6 .    4          1               . 78
80.05 - 3 - - -9- -.- - - -2-78 6 . - -4- - - - -1- - - - - - - -.
      5   3       9   .      27 8  6 .     4         1               .
      5   3       9   .      2  8  6 .     4         1               . 27
      5   3       9   .      2  8  6 .     4         1               . 27
      5   3       9   .      27 8  6 .     4         1               .
      5   3       9   .     2  78  6 .     4         1               .
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       5   3      9   .     2  78 6 .     4       1           .
       5   3      9   .      2 78 6 .     4       1           .
       5   3      9   .     2  7  6 .     4       1           . 78
       5   3      9   .     2  8  6 .      4      1           . 67
   90.05 - 3 - - -9- -.- - -2- -8- 6 . - -7- - 4 - -1- - - - - - - .
       5   3      9   .    2   8 6  .      7  4   1           .
       5   3      9   .     2  8 6  .   7      4  1           .
       5   3       9  .     2  8 6  .7        4   1           .
       5   3       9  .     2 8  6  .         4   1           . 67
       5   3       9  .     2 8  67 .         4   1           .
       5   3       9  .      28  6  .         4   1           . 67
       5   3       9  .      27  6  .       4     1           . 78
       5   3       9  .     728  6  .       4     1           .
       5   3       9  .      28  6  .       4     1           . 27
  100.05 - 3 - - - 9 -.- - - -278-6- . - - -4- - - -1- - - - - - - .
       5   3       9  .      2 7 6  .      4      1           . 78
       5   3      9   .      2 876  .      4      1           .
       5   3      9   .      2 8 6  .       4     1           . 67
       5   3      9   .      2 8 67 .       4     1           .
       1   3      9   .      2 7 6  .      4      .           . 15,78
       1   3      9   .   7    28  6 .    4       .           . 15
       1   3 7    9   .          2 6 .            .           . 248,15
       17  3     9    .     4    8 2 .            .           . 15,26
       1   3    9     .    4      826.            .           . 157
  110.01 - 3 - -9- - -.- - -4- - - 26. - - - - - - -.- - - - - - - . 157,28
       1   3   9      .    4      2 86            .           . 157
       1  3    9      .    4     2  86            .           . 157
       1  3   9       .    4   2    8.6           .           . 157
       1  3   9       .    4  2      86           .           . 157
       1  3   9       .    4 2       8 6          .           . 157
       1  3   9       .    42        8 6          .           . 157
       1 73   9       .    2         8 6          .           . 24,15
       1  3  7        .   24         8  6         .           . 15,79
       1  3  7        .   24         8  6         .           . 15,79
  120.01 -3- 97- - - -.- -2-4- - - - 8 -6- - - - - -.- - - - - - - . 15
       1  3  97       .  2 4         8  6         .           . 15
       1  3  97       . 2  4         8  6         .           . 15
       1  3  9 7      . 2  4         8   6        .           . 15
       1  3  9 7      .2   4         8   6        .           . 15
       1  3  9 7      .2   4         8   6        .           . 15
       1  3  9 7     .2    4         8   6        .           . 15
       1 3   9 7     .2    4         8   6        .           . 15
       1 3   9  7    2      4        8   6        .           . 15
       1 3   9   7  2.      4        8   6        .           . 15
  130.01 3 - 9 - - - 2.- - - - 4 - - 8 - 6 - - - - -.- - - - - - - . 15,27
       1 3    9     2 .  7     4     8   6        .           . 15
       1 3    9    2  .     7    4 8    6         .           . 15
       1 3    9    2  .           48.   6         .           . 15,47
       1 3    9    2  .           47.   6         .           . 15,78
       1 3     9    2 .      7    4 8.  6         .           . 15
```

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      1 3     9     2. 7        4  8.  6            .                .15
      1 3     9     2.         4   8.  6            .                .15,27
      1 3     9    72.        4    8.   6           .                .15
      1 3     9     2.        4    8.   6           .                .15,27
 140.01 3 - -9- - - 2.7 - - - 4 - -8. - 6 - - - - - -.- - - - - - - - .15
      1 3    9      2. 7      4    8.   6           .                .15
      1 3    9      2.  7     4    8.   6           .                .15
      1 3    9      2.   7    4    8.   6           .                .15
      1 3    9      2.    7    4   8.  6            .                .15
      1 3    9      2.    7    4   8.  6            .                .15
      1 3    9      2.   7     4   8.  6            .                .15
      1 3    9       2  7     4    8.  6            .                .15
      1 3    9       27       4    8.  6            .                .15
      1 3    9       2       4     8.  6            .                .15,27
 150.01 3 - -9- - - 72- - - -4- - -8. -6- - - - - - -.- - - - - - - - .15
      1 3    9      72       4      8   6           .                .15
      1 3    9       2       4      8   6           .                .15,27
      1 3    9       27      4      8   6           .                .15
      1 3    9       2  7    4      8   6           .                .15
      1 3    9       2  7    4      8   6           .                .15
      1 3    9       2 7     4      8   6           .                .15
      5 3    9       2 7      4     1   6           .                .18
      5 3    9       2 7      4     1   6           .                .18
      5 3    9     2 .             817 6            .                .14
 160.05 3 - - 9 - -2-.- - - - - - - -81 46- - - - 7 -.- - - - - - - - .
      5 3     9    2 .             8 1 4       7    .                .46
      5 3     9     2.             8 174            .                .46
      5 3      9    2        7     8 146            .                .
      5  3     9     .2     7      8 1 6            .                .14
      5  3     9     .2    7       8 1 6            .                .14
      5  3     9     .2      7   8  1 6             .                .14
      5  3     9     .2        7 8  1 6             .                .14
      5  3     9     .2          7  14              .                .46,78
      5  3     9     .2          87 14              .                .46
 170.05 -3- - -9- - -.2 - - - - -87 164 - - - - - - -.- - - - - - - - .
      5  3     9     .2          8  16 4            .                .67
      5  3     9     .2          8  16 74           .                .
      5  3      9    .2          8  1 7 4           .                .16
      5  3      9    . 2         8  1   4           .                .167
      5  3      9    .  2       7   1  4            .                .16,78
      5  3      9    .  2  7     8  14              .                .16
      5  3      9    .  72       8  1               .                .146
      5  3      9    .7  2       8 41               .                .16
      5  3     9     . 7 2       8 41               .                .16
 180.05 -3- - -9- - -.- 72- - - -8-41 - - - - - - - -.- - - - - - - - .16
      5  3     9     .   27      8 41               .                .16
      5  3     9     .   2 7     8 416              .                .
      5  3     9     .   2  7     8416              .                .
      5  3     9     .   27       4 16              .                .48
      5  3     9     .7    2     48 16              .                .
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```
          5  3     9    7.     2       48 16                 .               .
          5  3    9    7 .     2       48 16                 .               .
          5  3    9    7 .     2     4 8 16                  .               .
          5  3    9    7 .   2       4 8 16                  .               .
   190.05 -3- - 9 - - 7.- -2- - - 4 8 16- - - - - - - - - -.- - - - - - - - .
          5  3    9    7.    2     4    81 6                 .               .
          5  3    9      7   2       4  81 6                 .               .
          5  3    9       .  2         4 81 6                .               . 27
          5  3    9       .  2  7      4 81 6                .               .
          5  3    9       .  2     7    4816                 .               .
          5  3    9       .  2     7    8416                 .               .
          5  3    9       .  2     7    8416                 .               .
          5  3    9       .  2    7      8 16                .               . 14
          5  3    9       . 2     7      8 16                .               . 14
   200.05 -3- - -9- - -.-2- - 7 - - 8 16- - - - - - - - - -.- - - - - - - - . 14
*EOR
..
```

TIME	USINVE	DBO	RDEM	CPCR	SVCAC	CPCRL	SLQ	PARFD
	URINV1	DUI	RUSUR	IOR	ROE	ERRL	BSS	AMR
	URINV2	DSI	RNRTS	RDD	MTBD	CPRFX	TRQ	AMS
	URINV3	PINTRL	EDR	DTDR	PDR	DCPRF	ARQ	DSIARP
	SINVE	RINTRL	ERR	DRR	RRF1	CPRRF	EBBLOG	DRSRFD
	USCPI		RURS	RPSFD	RRF2	QF	TDTDR	
	BUCPI		RCPR	RAPFD	DRUSUR	DDR	DTDRL	ATBA
	DCPI		RCPUR	RRSFD	RRF3X	RTS	DRDFX	PTBA
	BSCPI		NCPR	RARFD	RRF3	NRTS	DRDF	PWDR
	ARQP		DCPRR		DERR	PBR	DRD	TRTD
			BCPRR		TERR	RCQ	MTL	BMXW
						NQ	PMR	
						OSTQ	PMP	

E+00	E-03	E-03	E+00	E-03	E+00	E+00	E+00	E-03
	E-03	E+00	E+00	E-03	E+00	E-03	E+00	E+00
	E-03	E+00	E-03	E-03	E+00	E-03	E-03	E+00
	E+00	E+00	E-03	E+00	E+00	E-03	E-03	E+00
	E+00	E-03	E-03	E-03	E-03	E-03	E+00	E-03
	E-03		E-03	E+00	E-03	E-03	E+00	
	E-03		E-03	E+00	E+00	E-03	E-03	E+00
	E+00		E-03	E-03	E-03	E-03	E+00	E+00
	E+00		E-03	E-03	E-03	E-03	E+00	E-03
	E-03		E-03		E+00	E-03	E+00	E-03
			E-03		E-03	E+00	E+00	E+00
						E-03	E+00	
						E-03	E+00	

0.00	0.000	0.00	1.1090	0.00	72.000	100.00	1.8330	0.00
	0.00	0.0000	0.0000	0.00	300.00	0.00	7.0000	0.
	0.000	10.000	0.00	0.00	270.52	0.000	0.00	0.
	0.0000	0.	0.00	0.	1.1090	500.00	0.000	9.000
	151.00	0.00	0.00	0.00	779.04	500.00	0.	0.00
	0.000		0.00	0.	500.00	483.07	0.	
	0.00		0.00	0.	1.5581	20.00	400.00	151.00
	0.0000		0.00	0.00	0.00	800.00	5.0000	151.28
	5.0000		0.00	0.00	625.00	200.00	2.7500	140.00
	0.00		0.00		1.0000	800.00	9.6250	0.00
			0.000		0.00	.2240	17.143	0.0000
						32.00	0.	
						24.00	300.00	

AD-A122 829 A SYSTEM DYNAMICS POLICY ANALYSIS MODEL OF THE AIR FORCE ENGINE MANAGEMENT SYSTEM(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST.. 3/3

UNCLASSIFIED G K LEMAIRE SEP 82 AFIT-LSSR-92-82 F/G 15/5 NL

END

FILMED

DTIC

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

1.00	54.813	0.00	1.0941	353.63	72.000	95.61	2.0359	0.00
	423.77	.0333	1.0963	0.00	300.00	884.07	5.9028	0.
	44.204	10.000	108.62	0.00	274.19	70.726	0.00	0.
	.5411	0.	983.41	0.	1.1014	500.00	0.000	9.000
	149.90	0.00	884.07	.03	775.65	500.00	0.	0.00
	17.681		56.46	0.	500.00	489.63	0.	
	161.74		353.36	0.	1.5513	24.67	299.59	150.97
	.0578		353.63	0.00	552.55	777.79	5.0000	150.25
	4.7805		238.60	0.00	801.53	194.55	2.7500	172.71
	0.00		.09		1.2824	799.91	9.6250	100.41
			2.258		884.07	.2763	17.143	1.0639
						39.49	0.	
						29.62	300.00	
26.00	27.639	62.57	.5522	178.08	72.000	77.09	4.0828	157.90
	247.90	1.1827	.5528	0.00	300.00	445.20	3.8796	0.
	22.260	10.576	113.37	-296.45	543.25	35.616	203.20	0.
	.9174	0.	444.73	0.	.5544	500.00	0.000	9.576
	147.88	146.45	445.20	127.31	568.61	500.00	0.	156.42
	8.904		464.80	0.	500.00	959.10	0.	
	117.43		177.89	0.	1.1372	99.22	286.50	149.24
	1.0279		178.08	156.42	278.25	74.07	5.2880	149.47
	3.8547		162.09	151.31	654.56	19.31	2.7500	694.57
	206.22		175.12		1.0473	793.21	9.6250	113.50
			18.592		445.20	1.1019	17.143	1.2152
						164.15	0.	
						123.11	300.00	
30.00	29.763	44.13	.5958	189.24	72.000	77.75	3.8989	74.27
	261.80	1.1341	.5953	142.17	300.00	473.11	3.7345	0.
	23.656	10.799	116.26	297.62	503.49	37.849	164.46	0.
	.9194	0.	473.59	0.	.5935	500.00	7.108	9.799
	147.73	98.25	473.11	121.69	578.38	500.00	0.	110.32
	9.462		453.53	0.	500.00	959.15	0.	
	121.34		189.44	0.	1.1568	90.49	283.87	149.07
	.9909		189.24	110.32	295.69	75.44	5.3993	149.16
	3.8877		168.51	87.09	658.92	18.38	2.7500	633.40
	157.35		167.20		1.0543	804.11	9.6250	116.13
			18.141		473.11	1.0186	17.143	1.2346
						141.80	0.	
						106.35	300.00	

35.00	29.414	41.50	.5881	188.62	72.000	77.13	3.6504	111.01
	261.98	1.1354	.5883	109.53	300.00	471.55	3.6922	0.
	23.577	10.802	118.55	115.05	510.10	37.724	158.21	0.
	.9525	0.	471.40	0.	.5888	500.00	5.477	9.802
	147.69	103.24	471.55	117.86	577.20	500.00	0.	103.74
	9.431		478.59	0.	500.00	953.57	0.	
	123.16		188.56	0.	1.1544	88.25	281.40	149.06
	1.0202		188.62	103.74	294.72	71.46	5.4009	149.08
	3.8566		170.32	105.69	658.68	17.76	2.7500	617.73
	152.74		168.26		1.0539	800.93	9.6250	118.60
			19.144		471.55	.9895	17.143	1.2675
						140.54	0.	
						105.41	300.00	
40.00	30.491	34.52	.6105	193.64	72.000	76.99	3.7806	110.81
	268.66	1.1387	.6098	133.15	300.00	484.10	3.6005	0.
	24.205	10.865	120.16	584.76	491.37	38.728	180.08	0.
	.9578	0.	484.65	0.	.6077	500.00	6.657	9.865
	147.60	114.99	484.10	117.95	582.68	500.00	0.	86.29
	9.682		476.82	0.	500.00	941.41	0.	
	125.08		193.86	0.	1.1654	85.08	279.88	149.00
	1.0254		193.64	86.29	302.56	69.18	5.4323	148.97
	3.8495		173.31	113.32	661.28	17.14	2.7500	595.54
	173.43		170.36		1.0581	801.42	9.6250	120.12
			19.073		484.10	.9545	17.143	1.2811
						135.16	0.	
						101.37	300.00	
50.00	37.259	104.29	.7456	238.00	72.000	73.99	3.8481	186.51
	328.60	1.2391	.7452	191.17	300.00	595.00	3.5226	0.
	29.750	10.497	145.66	-498.84	402.36	47.600	325.51	0.
	1.1397	0.	595.14	0.	.7444	500.00	9.558	9.497
	147.52	205.79	595.00	124.01	630.52	500.00	0.	260.72
	11.900		555.11	0.	500.00	787.60	0.	
	152.17		238.06	0.	1.2610	88.14	254.58	149.26
	1.1485		238.00	260.72	371.88	69.18	5.2486	149.07
	3.6993		212.39	200.05	695.94	17.44	2.7500	617.00
	315.95		185.12		1.1135	798.65	9.6250	145.42
			22.205		595.00	.9855	17.143	1.5353
						141.98	0.	
						106.48	300.00	

53.00	39.945	92.48	.8002	251.93	72.000	72.22	3.9216	205.33
	348.55	1.3095	.7989	198.77	300.00	629.84	3.5940	0.
	31.492	10.254	153.68	-163.04	374.91	50.387	327.60	0.
	1.2168	0.	631.35	0.	.7942	500.00	9.939	9.254
	147.59	205.79	629.84	128.88	647.96	500.00	0.	231.20
	12.597		600.66	0.	504.44	722.06	0.	
	160.50		252.54	0.	1.2959	91.54	246.53	149.44
	1.2283		251.93	231.20	393.65	71.07	5.1269	149.19
	3.6112		222.33	204.97	706.82	18.02	2.7500	640.80
	317.66		196.02		1.1309	797.70	9.6250	153.47
			24.026		629.84	1.0223	22.857	1.6368
						148.16	0.	
						111.12	400.00	
55.00	50.138	177.39	1.0010	322.04	72.000	69.82	4.0041	268.09
	437.67	1.3766	1.0028	350.77	395.14	805.09	3.4316	0.
	40.254	9.911	185.78	-252.84	394.75	64.407	572.47	0.
	1.4056	0.	805.39	0.	1.0065	500.00	17.539	8.911
	147.43	347.23	805.09	134.30	732.91	500.00	0.	443.46
	16.102		655.12	0.	504.44	739.70	0.	
	198.10		322.15	0.	1.4658	95.43	215.37	149.71
	1.3108		322.04	443.46	503.18	72.93	4.9554	149.32
	3.4911		279.12	309.06	771.91	18.60	2.7300	668.02
	554.94		205.05		1.2351	796.82	9.5550	184.63
			26.205		805.09	1.0646	22.857	1.9337
						155.12	0.	
						116.34	400.00	
60.00	41.455	62.58	.8290	265.58	72.000	66.54	4.1660	141.50
	369.00	1.5565	.8291	135.08	400.00	663.94	3.9476	0.
	33.197	9.556	167.10	-44.91	482.51	53.115	218.47	0.
	1.3594	0.	663.83	0.	.8294	500.00	6.754	8.556
	147.95	136.90	663.94	158.27	661.78	500.00	0.	156.46
	13.279		692.87	0.	504.44	839.76	0.	
	174.06		265.53	0.	1.3236	103.31	232.80	149.89
	1.4989		265.58	156.46	414.96	80.00	4.7780	149.61
	3.3270		239.57	132.48	718.98	20.36	2.6504	723.16
	211.71		245.45		1.1504	797.15	9.2763	167.20
			27.715		663.94	1.1529	22.857	1.8031
						167.65	0.	
						125.74	400.00	

65.00	45.216	103.38	.9040	289.00	72.000	66.49	4.3159	231.36
	399.94	1.5801	.9043	208.40	400.00	722.49	3.9436	0.
	36.125	9.343	178.39	243.41	442.46	57.800	372.29	0.
	1.4114	0.	722.95	0.	.9048	500.00	10.420	8.343
	147.94	240.78	722.49	171.62	691.92	500.00	0.	258.44
	14.450		696.61	0.	504.44	799.38	0.	
	185.89		289.18	0.	1.3838	110.88	221.77	150.08
	1.4895		289.00	258.44	451.56	85.66	4.6714	149.86
	3.3246		258.21	238.66	740.94	21.80	2.6025	776.13
	361.87		247.16		1.1855	797.16	9.1089	178.23
			27.864		722.49	1.2374	22.857	1.8927
						179.92	0.	
						134.94	400.00	
70.00	42.899	74.30	.8575	275.58	72.000	65.93	4.4559	190.64
	383.03	1.5959	.8580	216.75	400.00	688.94	4.1761	0.
	34.447	9.186	173.93	178.17	466.45	55.116	279.81	0.
	1.4005	0.	688.54	0.	.8594	500.00	10.838	8.186
	148.18	181.50	688.94	177.07	673.75	500.00	0.	185.75
	13.779		705.55	0.	504.44	813.35	0.	
	180.54		275.42	0.	1.3475	118.19	225.96	150.22
	1.5228		275.58	185.75	430.59	92.09	4.5928	150.10
	3.2966		249.58	184.67	728.35	23.36	2.5673	827.30
	268.97		252.95		1.1654	797.67	8.9855	174.04
			28.222		688.94	1.3198	22.857	1.8609
						191.30	0.	
						143.47	400.00	
75.00	40.245	62.59	.8054	258.60	72.000	67.16	4.5362	160.62
	359.49	1.5565	.8049	160.43	400.00	646.50	4.2965	0.
	32.325	9.241	163.36	117.46	496.64	51.720	237.63	0.
	1.3174	0.	646.10	0.	.8063	500.00	8.022	8.241
	148.30	154.71	646.50	175.28	652.54	500.00	0.	156.48
	12.930		664.86	0.	504.44	851.98	0.	
	169.58		258.44	0.	1.3051	122.48	236.52	150.20
	1.4725		258.60	156.48	404.06	96.67	4.6204	150.24
	3.3579		234.30	156.86	712.44	24.37	2.5797	857.37
	229.61		249.70		1.1399	798.64	9.0289	163.48
			26.594		646.50	1.3695	22.857	1.7494
						197.30	0.	
						147.98	400.00	

80.00	41.227	59.18	.8247	263.46	72.000	68.08	4.5505	171.09
	365.39	1.5103	.8245	123.73	400.00	658.66	4.2956	0.
	32.933	9.274	164.19	270.71	485.03	52.693	254.94	0.
	1.3124	0.	658.82	0.	.8240	500.00	6.186	8.274
	148.30	167.80	658.66	169.55	659.62	500.00	0.	147.95
	13.173		655.43	0.	504.44	900.41	0.	
	170.83		263.53	0.	1.3192	123.26	235.83	150.22
	1.4253		263.46	147.95	411.66	98.69	4.6372	150.27
	3.4039		236.46	169.22	717.00	24.72	2.5872	862.81
	248.75		239.54		1.1472	799.66	9.0552	164.17
			26.217		658.66	1.3799	22.857	1.7519
						197.55	0.	
						148.16	400.00	
85.00	41.424	62.70	.8283	265.52	72.000	68.05	4.5065	161.46
	368.15	1.4999	.8285	166.54	400.00	663.79	4.2476	0.
	33.190	9.319	165.73	326.98	482.92	53.104	258.92	0.
	1.3242	0.	663.64	0.	.8290	500.00	8.327	8.319
	148.25	166.24	663.79	165.54	661.62	500.00	0.	156.75
	13.276		661.10	0.	504.44	930.26	0.	
	172.49		265.46	0.	1.3232	120.89	234.29	150.18
	1.4249		265.52	156.75	414.87	97.08	4.6597	150.19
	3.4026		238.96	163.87	718.92	24.19	2.5973	846.20
	250.60		237.24		1.1503	800.52	9.0905	165.71
			26.444		663.79	1.3548	22.857	1.7670
						192.91	0.	
						144.68	400.00	
90.00	46.890	120.56	.9378	298.60	72.000	67.22	4.5082	199.18
	411.05	1.5125	.9378	267.60	400.00	746.50	4.1334	0.
	37.325	9.221	180.02	-261.09	426.51	59.720	374.72	0.
	1.4071	0.	747.35	0.	.9365	500.00	13.380	8.221
	148.13	230.56	746.50	166.55	704.61	500.00	0.	301.40
	14.930		684.12	0.	504.44	796.49	0.	
	189.06		298.94	0.	1.4092	120.97	220.45	150.27
	1.4497		298.60	301.40	466.56	96.63	4.6106	150.19
	3.3612		263.61	217.19	749.94	24.16	2.5753	846.31
	361.34		238.38		1.1999	800.00	9.0135	179.55
			27.365		746.50	1.3549	22.857	1.9023
						193.55	0.	
						145.17	400.00	

95.00	46.067	80.22	.9202	296.99	72.000	64.86	4.5295	187.85
	411.32	1.5877	.9213	198.22	400.00	742.48	4.2354	0.
	37.124	9.014	185.39	362.91	434.68	59.398	294.06	0.
	1.4825	0.	741.80	0.	.9248	500.00	9.911	8.014
	148.24	185.72	742.48	174.86	699.91	500.00	0.	200.55
	14.850		740.69	0.	504.44	825.47	0.	
	193.30		296.72	0.	1.3998	122.12	214.66	150.40
	1.5635		296.99	200.55	464.05	97.22	4.5070	150.23
	3.2432		267.99	184.83	748.43	24.36	2.5288	854.85
	284.15		254.78		1.1975	799.66	8.8508	185.34
			29.628		742.48	1.3672	22.857	1.9770
						195.73	0.	
						146.80	400.00	
100.00	43.138	54.28	.8628	275.99	72.000	65.50	4.5488	156.19
	383.59	1.5917	.8628	178.08	400.00	689.97	4.2939	0.
	34.498	9.098	173.48	784.65	463.60	55.197	254.90	0.
	1.3927	0.	689.97	0.	.8626	500.00	8.904	8.098
	148.29	162.39	689.97	178.88	675.03	500.00	0.	135.71
	13.799		699.50	0.	504.44	953.58	0.	
	180.23		275.99	0.	1.3501	123.16	226.46	150.31
	1.5449		275.99	135.71	431.23	98.11	4.5491	150.26
	3.2748		249.47	160.75	728.74	24.58	2.5477	862.15
	246.00		260.70		1.1660	799.68	8.9168	173.54
			27.980		689.97	1.3789	22.857	1.8539
						197.37	0.	
						148.03	400.00	
105.00	41.325	58.15	.8254	266.99	72.000	66.32	4.5723	178.42
	371.97	1.5666	.8265	218.72	400.00	667.48	4.3282	0.
	33.374	9.117	170.77	-126.67	484.63	53.399	244.09	0.
	1.3757	0.	666.50	0.	.8300	500.00	10.936	8.117
	148.33	165.37	667.48	176.98	661.99	500.00	0.	145.39
	13.350		693.75	0.	500.00	961.21	0.	
	176.45		266.60	0.	1.3240	124.44	228.99	150.32
	1.5078		266.99	145.39	417.18	99.16	4.5587	150.30
	3.3158		244.16	173.56	720.31	24.86	2.5520	871.07
	233.16		253.14		1.1525	799.58	8.9320	171.01
			27.750		667.48	1.3930	14.286	1.8224
						199.52	0.	
						149.64	250.00	

110.00	24.159	.00	.4830	154.94	72.000	74.55	4.4299	2.21
	215.28	1.3542	.4832	0.00	250.00	387.34	4.7581	0.
	19.367	9.822	97.57	-.00	517.56	30.987	0.00	0.
	.8065	0.	387.22	0.	.4836	500.00	0.000	8.822
	148.76	.06	387.34	159.00	550.91	500.00	0.	.00
	7.747		419.29	0.	500.00	957.99	0.	
	102.14		154.89	0.	1.1018	116.81	302.37	149.32
	1.1703		154.94	.00	242.09	96.88	4.9112	150.39
	3.7275		139.94	.14	645.52	23.80	2.7101	817.66
	.06		224.98		1.0328	802.80	9.4855	97.63
			16.772		387.34	1.3128	14.286	1.0653
						184.27	0.	
						138.21	250.00	
115.00	24.366	.00	.4874	155.72	72.000	79.85	4.2352	.00
	215.94	1.1133	.4873	0.00	250.00	389.31	4.3065	0.
	19.465	10.546	96.99	-.00	512.91	31.145	0.00	0.
	.7743	0.	389.39	0.	.4870	500.00	0.000	9.546
	148.31	.00	389.31	131.01	551.75	500.00	0.	.00
	7.786		386.28	0.	500.00	949.33	0.	
	100.94		155.76	0.	1.1035	106.77	303.04	149.34
	.9065		155.72	.00	243.32	89.40	5.2731	149.80
	3.9925		139.83	.00	645.83	21.86	2.7500	747.37
	.00		163.85		1.0333	803.51	9.6250	96.96
			15.451		389.31	1.2010	14.286	1.0341
						167.83	0.	
						125.87	250.00	
120.00	24.246	25.50	.4850	154.96	72.000	81.01	3.9926	42.25
	214.99	.9987	.4849	97.17	250.00	387.40	3.9212	0.
	19.370	11.003	96.73	-60.40	515.44	30.992	71.45	0.
	.7746	0.	387.48	0.	.4846	500.00	4.858	10.003
	147.92	44.09	387.40	111.04	551.15	500.00	0.	63.74
	7.748		387.71	0.	500.00	938.47	0.	
	100.63		154.99	0.	1.1023	94.89	303.28	149.00
	.8490		154.96	63.74	242.12	80.58	5.5014	149.32
	4.0504		139.23	43.79	645.53	19.54	2.7500	664.20
	66.59		143.93		1.0329	804.85	9.6250	96.72
			15.509		387.40	1.0692	14.286	1.0332
						148.14	0.	
						111.10	250.00	

125.00	24.374	29.32	.4876	156.15	72.000	81.10	3.7508	53.39
	216.79	.9569	.4875	95.97	250.00	390.36	3.6674	0.
	19.518	11.279	97.91	-105.92	512.76	31.229	83.40	0.
	.7832	0.	390.29	0.	.4876	500.00	4.799	10.279
	147.67	52.56	390.36	101.94	551.91	500.00	0.	73.30
	7.807		391.54	0.	500.00	917.59	0.	
	101.70		156.12	0.	1.1038	83.74	302.07	148.76
	.8432		156.15	73.30	243.98	71.07	5.6397	148.92
	4.0551		140.88	53.08	645.99	17.23	2.7500	586.18
	78.60		140.49		1.0336	804.82	9.6250	97.93
			15.661		390.36	.9435	14.286	1.0438
						130.76	0.	
						98.07	250.00	
130.00	28.392	66.44	.5692	178.79	72.000	80.51	3.5227	75.27
	246.46	.9554	.5678	159.68	250.00	446.97	3.3637	0.
	22.349	11.452	107.41	-482.34	439.21	35.758	158.98	0.
	.8403	0.	448.06	0.	.5637	500.00	7.984	10.452
	147.36	91.62	446.97	99.00	570.92	500.00	0.	166.09
	8.939		408.90	0.	500.00	789.07	0.	
	112.76		179.23	0.	1.1418	73.87	292.87	148.59
	.8617		178.79	166.09	279.36	62.69	5.7259	148.55
	4.0255		156.96	83.84	654.84	15.18	2.7500	517.06
	150.99		141.23		1.0477	805.02	9.6250	107.13
			16.356		446.97	.8325	14.286	1.1375
						115.22	0.	
						86.42	250.00	
135.00	29.731	49.27	.5937	193.04	72.000	77.21	3.5247	178.99
	269.80	1.0632	.5946	85.24	250.00	482.59	3.3094	0.
	24.130	11.141	125.49	63.12	421.09	38.608	215.28	0.
	1.0106	0.	481.39	0.	.5980	500.00	4.262	10.141
	147.31	152.33	482.59	102.88	579.51	500.00	0.	123.18
	9.652		509.35	0.	500.00	761.68	0.	
	128.89		192.56	0.	1.1590	73.95	274.21	148.80
	1.0106		193.04	123.18	301.62	58.05	5.5704	148.56
	3.8605		178.61	168.15	660.81	14.63	2.7500	517.63
	211.01		157.61		1.0573	798.76	9.6250	125.79
			20.374		482.59	.8269	14.286	1.3343
						117.05	0.	
						89.29	250.00	

140.00	27.668	29.53	.5534	176.76	72.000	77.74	3.5767	93.96
	245.05	1.0986	.5534	108.41	250.00	441.91	3.4118	0.
	22.095	11.207	109.99	643.08	451.73	35.353	164.92	0.
	.8843	0.	442.05	0.	.5530	500.00	5.421	10.207
	147.41	103.39	441.91	112.31	568.24	500.00	0.	73.82
	8.838		444.67	0.	500.00	305.41	0.	
	114.70		176.82	0.	1.1365	76.15	290.03	148.69
	.9984		176.76	73.82	276.19	60.18	5.6036	148.64
	3.8869		158.43	98.52	654.05	15.14	2.7500	533.04
	159.50		169.63		1.0465	798.94	9.6250	109.97
			17.787		441.91	.8517	14.286	1.1791
						122.48	0.	
						91.86	250.00	
145.00	28.465	43.41	.5692	182.33	72.000	78.14	3.6266	131.93
	252.88	1.0902	.5693	117.39	250.00	455.82	3.4222	0.
	22.791	11.144	113.85	350.04	439.21	36.465	204.31	0.
	.9077	0.	455.77	0.	.5695	500.00	5.869	10.144
	147.42	132.13	455.82	113.69	572.39	500.00	0.	108.53
	9.116		452.06	0.	500.00	813.49	0.	
	118.37		182.31	0.	1.1448	78.29	286.16	148.77
	.9749		182.33	108.53	284.89	61.75	5.5718	148.72
	3.9068		164.11	133.16	656.22	15.55	2.7500	548.00
	198.45		162.99		1.0500	798.87	9.6250	113.84
			18.083		455.82	.8756	14.286	1.2119
						125.97	0.	
						94.47	250.00	
147.00	27.637	47.16	.5522	178.17	72.000	78.12	3.6470	127.73
	247.79	1.0904	.5527	98.18	250.00	445.42	3.4629	0.
	22.271	11.121	112.97	-60.21	452.76	35.634	184.07	0.
	.9061	0.	444.90	0.	.5545	500.00	4.909	10.121
	147.46	121.78	445.42	113.47	568.63	500.00	0.	117.89
	8.908		454.52	0.	500.00	827.56	0.	
	117.09		177.96	0.	1.1373	79.17	286.94	148.79
	.9769		178.17	117.89	278.39	62.49	5.5605	148.75
	3.9060		162.34	125.61	654.60	15.74	2.7500	554.19
	179.16		162.58		1.0474	798.83	9.6250	113.06
			18.181		445.42	.8854	14.286	1.2038
						127.42	0.	
						95.56	250.00	

150.00	26.155	40.68	.5227	168.29	72.000	78.56	3.6657	99.20
	234.05	1.0798	.5231	86.38	250.00	420.72	3.5214	0.
	21.036	11.163	106.61	-149.54	478.27	33.657	144.36	0.
	.8620	0.	420.37	0.	.5243	500.00	4.319	10.163
	147.52	93.12	420.72	113.17	561.09	500.00	0.	101.71
	8.414		436.32	0.	500.00	844.43	0.	
	110.64		168.15	0.	1.1222	79.99	293.29	148.76
	.9612		168.29	101.71	262.95	63.48	5.5813	148.78
	3.9282		152.75	95.62	650.74	15.95	2.7500	559.90
	140.04		162.12		1.0412	799.23	9.6250	106.71
			17.453		420.72	.8950	14.286	1.1432
						128.47	0.	
						96.35	250.00	
156.00	27.203	44.68	.5442	173.85	72.000	79.19	3.6798	116.85
	241.08	1.0459	.5441	114.34	250.00	434.63	3.5058	0.
	21.732	11.179	108.27	141.00	459.43	34.771	173.98	0.
	.8632	0.	434.74	0.	.5437	500.00	5.717	10.179
	147.51	115.56	434.63	110.19	565.94	500.00	0.	111.70
	8.693		429.86	0.	500.00	869.84	0.	
	112.65		173.89	0.	1.1319	80.60	291.75	148.77
	.9281		173.85	111.70	271.65	64.43	5.5897	148.80
	3.9593		156.13	116.42	652.91	16.13	2.7500	564.20
	168.26		155.22		1.0447	799.74	9.6250	108.25
			17.194		434.63	.9024	14.286	1.1532
						129.13	0.	
						96.85	250.00	
157.00	27.218	41.77	.5443	174.27	72.000	79.15	3.6737	114.22
	241.67	1.0445	.5444	112.12	250.00	435.68	3.5070	0.
	21.784	11.179	108.72	179.48	459.31	34.854	166.68	0.
	.8675	0.	435.66	0.	.5445	500.00	5.606	10.179
	147.51	111.50	435.68	109.67	566.13	500.00	0.	104.43
	8.714		432.35	0.	500.00	877.37	0.	
	113.09		174.26	0.	1.1323	80.33	291.29	148.78
	.9295		174.27	104.43	272.30	64.49	5.5895	148.79
	3.9574		156.74	112.70	653.07	16.12	2.7500	562.33
	161.08		154.87		1.0449	800.03	9.6250	108.71
			17.294		435.68	.8998	20.000	1.1581
						128.51	0.	
						96.38	350.00	

160.00	37.623	117.43	.7514	241.58	72.000	76.87	3.6871	223.25
	332.36	1.0833	.7525	244.73	349.61	603.96	3.2568	0.
	30.198	10.881	145.80	118.15	465.27	48.317	430.26	0.
	1.0982	0.	604.12	0.	.7551	500.00	12.237	9.881
	147.26	280.44	603.96	108.99	634.28	500.00	0.	293.58
	12.079		510.77	0.	500.00	899.96	0.	
	152.09		241.65	0.	1.2686	80.92	254.66	149.04
	1.0045		241.58	293.58	377.48	64.18	5.4405	148.81
	3.8434		215.48	265.12	698.74	16.06	2.7500	566.44
	418.02		156.88		1.1180	799.86	9.6250	145.34
			20.431		603.96	.9061	20.000	1.4984
						129.56	0.	
						97.17	350.00	
165.00	34.722	58.43	.6949	221.25	72.000	73.51	3.7806	139.44
	307.14	1.2407	.6944	130.33	350.00	553.11	3.5696	0.
	27.656	10.571	138.14	-16.58	503.69	44.249	211.01	0.
	1.1155	0.	553.50	0.	.6931	500.00	6.517	9.571
	147.57	133.27	553.11	119.59	612.59	500.00	0.	146.07
	11.062		563.60	0.	500.00	927.14	0.	
	143.81		221.40	0.	1.2252	85.08	261.84	149.19
	1.1809		221.25	146.07	345.70	66.57	5.2857	148.97
	3.6753		198.13	132.55	682.85	16.84	2.7500	595.54
	204.49		189.48		1.0926	798.14	9.6250	138.16
			22.544		553.11	.9507	20.000	1.4850
						137.39	0.	
						103.04	350.00	
170.00	38.094	81.22	.7633	240.70	72.000	72.43	3.8787	183.19
	333.16	1.3202	.7619	183.49	350.00	601.75	3.5814	0.
	30.087	10.339	147.46	19.58	458.55	48.140	297.27	0.
	1.1697	0.	602.94	0.	.7575	500.00	9.174	9.339
	147.58	188.12	601.75	131.70	635.13	500.00	0.	203.05
	12.035		578.80	0.	500.00	858.93	0.	
	153.84		241.18	0.	1.2703	89.55	252.70	149.34
	1.2244		240.70	203.05	376.09	69.86	5.1696	149.12
	3.6217		213.10	185.59	698.05	17.69	2.7500	626.84
	288.10		200.80		1.1169	797.97	9.6250	147.30
			23.152		601.75	1.0004	20.000	1.5710
						144.73	0.	
						108.55	350.00	

175.00	36.628	64.91	.7312	237.55	72.000	70.62	4.0095	191.82
	331.40	1.4131	.7326	107.13	350.00	593.88	3.7595	0.
	29.694	10.022	153.19	-140.03	478.66	47.510	250.02	0.
	1.2367	0.	592.59	0.	.7367	500.00	5.357	9.022
	147.76	170.63	593.88	140.77	627.85	500.00	0.	162.28
	11.878		625.09	0.	500.00	862.33	0.	
	158.01		237.04	0.	1.2557	95.69	246.53	149.56
	1.3111		237.55	162.28	371.17	74.18	5.0112	149.34
	3.5309		218.71	181.11	695.59	18.86	2.7500	669.85
	244.66		213.29		1.1129	797.31	9.6250	153.47
			25.004		593.88	1.0682	20.000	1.6344
						155.17	0.	
						116.38	350.00	
177.00	34.072	48.29	.6807	219.66	72.000	71.07	4.0520	136.50
	306.84	1.4229	.6814	87.32	350.00	549.15	3.9753	0.
	27.457	10.059	141.60	-129.52	514.20	43.932	176.75	0.
	1.1573	0.	548.53	0.	.6837	500.00	4.366	9.059
	147.88	117.51	549.15	144.33	609.30	500.00	0.	120.74
	10.983		593.08	0.	500.00	913.90	0.	
	146.37		219.41	0.	1.2186	97.73	258.11	149.52
	1.3001		219.66	120.74	343.22	76.16	5.0293	149.42
	3.5535		201.63	123.87	681.61	19.32	2.7500	684.12
	172.39		217.35		1.0906	797.64	9.6250	141.89
			23.723		549.15	1.0914	20.000	1.5257
						158.21	0.	
						118.66	350.00	
180.00	33.242	49.80	.6649	212.65	72.000	72.53	4.0985	114.65
	295.14	1.3936	.6648	122.75	350.00	531.63	3.9029	0.
	26.582	10.153	133.05	189.35	526.41	42.530	195.59	0.
	1.0730	0.	531.68	0.	.6647	500.00	6.138	9.153
	147.90	122.16	531.63	146.68	602.66	500.00	0.	124.50
	10.633		541.62	0.	500.00	952.24	0.	
	138.56		212.67	0.	1.2053	99.98	266.93	149.45
	1.2352		212.65	124.50	332.27	78.54	5.0767	149.49
	3.6263		191.23	117.74	676.13	19.83	2.7500	699.89
	189.45		213.00		1.0818	798.40	9.6250	133.07
			21.665		531.63	1.1176	20.000	1.4280
						161.26	0.	
						120.94	350.00	

185.00	31.373	26.02	.6270	201.83	72.000	74.15	4.1330	125.74
	280.75	1.3285	.6275	104.16	350.00	504.56	3.9720	0.
	25.228	10.219	127.95	557.12	558.21	40.365	160.93	0.
	1.0339	0.	504.16	0.	.6289	500.00	5.208	9.219
	147.97	109.06	504.56	142.37	590.12	500.00	0.	65.06
	10.091		522.88	0.	500.00	958.18	0.	
	132.70		201.66	0.	1.1802	101.67	271.93	149.45
	1.1596		201.83	65.06	315.35	81.33	5.1096	149.55
	3.7077		183.22	116.11	667.68	20.42	2.7500	711.72
	155.72		197.77		1.0683	799.32	9.6250	128.07
			20.915		504.56	1.1378	20.000	1.3712
						163.23	0.	
						122.42	350.00	
190.00	29.476	55.92	.5893	189.14	72.000	75.86	4.0678	91.28
	262.78	1.2496	.5895	105.78	350.00	472.86	3.9227	0.
	23.643	10.462	119.08	-484.22	593.93	37.829	145.17	0.
	.9592	0.	472.67	0.	.5902	500.00	5.289	9.462
	147.92	90.97	472.86	135.12	577.55	500.00	0.	139.79
	9.457		483.43	0.	500.00	956.67	0.	
	123.73		189.07	0.	1.1551	98.50	280.86	149.29
	1.0830		189.14	139.79	295.54	79.91	5.2308	149.44
	3.7932		170.98	92.37	658.88	19.83	2.7500	689.47
	139.88		185.62		1.0542	801.20	9.6250	119.14
			19.337		472.86	1.1048	20.000	1.2751
						156.64	0.	
						117.48	350.00	
195.00	33.249	68.39	.6655	211.75	72.000	76.03	4.0153	112.96
	292.71	1.2024	.6650	164.27	350.00	529.37	3.7748	0.
	26.469	10.496	129.90	-57.58	525.95	42.350	240.48	0.
	1.0224	0.	529.78	0.	.6635	500.00	8.213	9.496
	147.77	151.70	529.37	127.42	602.23	500.00	0.	170.97
	10.587		501.44	0.	500.00	952.45	0.	
	135.54		211.91	0.	1.2045	95.97	270.27	149.30
	1.0631		211.75	170.97	330.86	77.65	5.2481	149.35
	3.8013		188.54	150.69	675.43	19.29	2.7500	671.76
	232.27		175.99		1.0807	800.99	9.6250	129.73
			20.058		529.37	1.0762	20.000	1.3749
						152.78	0.	
						114.59	350.00	

200.00	35.006	38.05	.7003	223.66	72.000	74.23	3.9616	143.66
	310.04	1.2474	.7001	150.82	350.00	559.14	3.7392	0.
	27.957	10.390	139.07	762.27	499.79	44.731	222.37	0.
	1.1064	0.	559.28	0.	.6996	500.00	7.541	9.390
	147.74	143.66	559.14	126.48	614.85	500.00	0.	95.12
	11.183		549.59	0.	500.00	937.58	0.	
	144.72		223.71	0.	1.2297	93.42	260.98	149.36
	1.1440		223.66	95.12	349.46	75.67	5.1951	149.26
	3.7113		200.73	143.32	684.73	18.79	2.7500	653.93
	214.83		185.09		1.0956	801.11	9.6250	139.02
			21.984		559.14	1.0477	20.000	1.4794
						148.64	0.	
						111.48	350.00	

APPENDIX E

RESULTS FOR EXPERIMENTAL RUN 2

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FHP=1  SINVE=2  NRTS=3  NCPR=4  USINVE=5  DSI=6  RINTRL=7
BSCPI=8  DCPI=9


  0.000T           .250T           .500T           .750T          1.000T 1
140.000         145.000         150.000         155.000         160.000  2
  0.000            .100            .200            .300            .400  34
  0.000          10.000          20.000          30.000          40.000  56
  0.000            .500           1.000           1.500           2.000  7
  0.000           2.000           4.000           6.000           8.000  89
  0.04 - - - - - - - -6- 1 - - - - - - 3 - - - 8 - - - -.- - - - - - - -2- . 4579
     5               6 1          3.     4        .        2     . 579,48
     5  9            6 1         3 .  8           . 4   2        . 57
     5    9          6 1        3  .8           4 .    2         . 57
     5     9         6 1       3   8      4       .    2         . 57
     5       9       6 1      3   8.4             .    2         . 57
     5       9       6 1     3   8 4              .    2         . 57
     5        9     .6 1    3    84.              .   2          . 57
     5        9     .6 1   3     84.              .   2          . 57
     5        9     .6 1  3      84.              .   2          . 57
 10.05 - - - -9- - -.6 1 3 - - - 8 4 - - - - - - -.- 2 - - - - - . 57
     5        9     .6 13        8 .4             .  2           . 57
     5        9     . 61         8 .4             . 2            . 13,57
     5        9     . 31         8 .4             . 2            . 36,57
     5        9     .361         8 4              .2             . 57
     5        9     3 61         8 4              .2             . 57
     5        9    3. 61         8 4.             .2             . 57
     5        9  3  .  1        48 .              .2             . 16,57
     5        9 3   .  1       4 8 .               2             . 16,57
     5        93    .  1       4 8 .               2             . 16,57
 20.05 - - - 93- - -.- 1 - - -4- 8 . - - - - - - - -2- - - - - - - . 16.57
     5       3      .  1      4  8 .               2             . 16.57,39
     5      39      .  16     4   8.              2.             . 57
     5     3 9      .  16      4  8.              2.             . 57
     5    3  9      .  16      4  8.            2 .              . 57
     5   3   9      .  16     4   8.            2 .              . 57
     5  3    9      .  16    4    8.            2 .              . 57
     5  3    9      .  1 6   4    8.            2 .              . 57
     5  3    9      .  1 6   4    8.           2  .              . 57
     5  3   9       .  1 6    4   8.           2  .              . 57
 30.05 -3- -9- - - -.- 1 6 - -4- -8. - - - - -2- -.- - - - - - - - . 57
     5  3   9       .  1 6     4  8.          2   .              . 57
     5  3    9      .  1 6     4  8.          2 ` .              . 57
     5  3    9      .  1  6    4  8.         2    .              . 57
     5  3    9      .  1  6    4  8.         2    .              . 57
     5  3    9      .  1  6    4  8.         2    .              . 57
```

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        5  3    9      . 1  6   4   8.        2     .               . 57
        5  3    9      . 1  6   4   8.        2     .               . 57
        5  3    9      . 1  6    4  8.        2     .               . 57
        5  3    9      . 1   6   4  8.       2      .               . 57
    40.05 -3- - 9 - - -.- 1 - 6 - 4 -8. - - - 2 - - -.- - - - - - - - . 57
        5  3    9      . 1   6   4  8.      2       .               . 57
        5  3    9      . 1   6    4 8.      2       .               . 57
        5  3    9      . 1   6    4 8.     2        .               . 57
        5  3    9      . 1    6    48.     2        .               . 57
        5  3    9      . 1    6    4 .     2        .               . 57,48
        5  3    9      . 1    6    4 .    2         .               . 57,48
        5  3    9      . 1    6    84.    2         .               . 57
        5  3    9      . 1    6    84.   2          .               . 57
        5  3    9      . 1    6    8 4   2          .               . 57
    50.05 -3- - -9- - -.- 1 - - 6 - 8 . 42- - - - - -.- - - - - - - - . 57
        5  3     9     . 1     6   8 . 42           .               . 57
        5  3     9     . 1     6  8  . 24           .               . 57
        5  3     9     .       6  8  .2 4           .        1      . 57
        5  3    49     .       6    82              .        1      . 57
       45 3     9      .        2    8              .        1      . 26.47
        4 5 3 9        .  2   76     . 8            .        1      .
        4  53          . 2  6        .  8  7        .        1      . 39
           935         . 62          .   87     1   .               . 24
        .  9 35        .6   2   4    17  8          .               .
    60.0. - -935- - - -6- - - 27- -1- . - 8 - - - - -.- - - - - - - - . 24
        .   9 3        67  4    1    .   8          .               . 12,35
        .   9 3     7 6     1  2     .8           4.                . 35
        .    593       6 1      2  8.               .   4           . 37
        .7   5  3      16        28 .               .4              . 39
        7   5    39    1 6       2  .             4.                . 28
        7  5     3 9   1  6     8 2 .               .  4            .
        7 5       39   1   6    8    2.             .   4           .
        75        3 9  1    6 8      2              .   4           .
        5         3  9 1     6 8     .2             .   4           . 57
    70.05 - - - - 3 -9-1- - - 68- -4- . 2 - - - - - -.- - - - - - - - . 57
        5         3 9  1      48     .  2           .               . 46,57
        5         39   1      4 8    .  2           .               . 46,57
        5         3    1      46 8   .  2           .               . 57,39
        5        93    1     4 6  8  . 2            .               . 57
        5        93    1     4  6  8 . 2            .               . 57
        5       9 3    1     4  6  8 . 2            .               . 57
        5       9 3    1     4  6   8. 2            .               . 57
        5      9  3    1     4  6   8.2             .               . 57
        5      9  3    1     4   6  8.2             .               . 57
    90.05 - - -9-3- - -1- - - 4 - 6 - 82- - - - - - -.- - - - - - - - . 57
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    5      9 3    1      4   6   2              .              . 57,28
    5       93    1      4   6   2              .              . 57,28
    5       93    1      4   6   2              .              . 57,28
    5        3    1      4   6  28              .              . 57,39
    5       39    1      4    6 28              .              . 57
    5       39    1      4    6 28              .              . 57
    5     3 9     1      4    62 8              .              . 57
    5     3 9     1       4   62 8              .              . 57
    5    3  9     1       4   62 8              .              . 57
90.05 - 3 -9- - - -1- - - - -4-2- 8 - - - - - - -.- - - - - - - . 26,57
    5  3    9     1         4 2  8              .              . 26,57
    5  3    9     1         42 6 8              .              . 57
    5  3    9     1         42 68.              .              . 57
    5 3     9     1         42 68.              .              . 57
    5 3     9     1          2  68.             .              . 24,57
    5 3     9     1          2  68.             .              . 24,57
    5 3     9     1        42   68.             .              . 57
    5 3     9     1       4 2    6.             .              . 57,68
..
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TIME	USINVE	DBO	RDEM	CPCR	SVCAC	CPCRL	SLG	PARFD
	URINV1	DUI	RUSUR	IOR	ROE	ERRL	BSS	AMR
	URINV2	DSI	RNRTS	RDD	MTBD	CPRFX	TRQ	AMS
	URINV3	PINTRL	EDR	DTDR	PDR	DCPRF	ARQ	DSIARF
	SINVE	RINTRL	ERR	DRR	RRF1	CPRRF	EBBLOG	DRSRFD
	USCPI		RURS	RPSFD	RRF2	QF	TDTDR	
	BUCPI		RCPR	RAPFD	DRUSUR	DDR	DTDRL	ATBA
	DCPI		RCPUR	RRSFD	RRF3X	RTS	DRDFX	PTBA
	BSCPI		NCPR	RARFD	RRF3	NRTS	DRDF	PWDR
	ARQP		DCPRR		DERR	PBR	DRD	TRTD
			BCPRR		TERR	RCQ	MTL	BMXW
						NQ	PMR	
						OSTQ	FHP	

E+00	E+00	E-03	E+00	E-03	E+00	E+00	E+00	E+00
	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00
	E-03	E+00	E+00	E-03	E+00	E-03	E+00	E+00
	E+00	E+00	E-03	E+00	E+00	E-03	E-03	E+00
	E+00	E+00	E+00	E-03	E+00	E-03	E+00	E+00
	E-03		E-03	E+00	E-03	E-03	E+00	
	E-03		E-03	E+00	E+00	E-03	E+00	E+00
	E+00		E-03	E+00	E+00	E-03	E+00	E+00
	E+00		E-03	E+00	E+00	E-03	E+00	E+00
	E+00		E-03		E+00	E-03	E+00	E-03
			E-03		E+00	E+00	E+00	E+00
						E-03	E+00	
						E-03	E+00	

0.00	0.0000	0.00	1.1090	0.00	72.000	100.00	1.8330	0.0000
	0.0000	0.0000	0.0000	0.0000	300.00	0.0000	15.000	0.
	0.00	10.000	0.0000	0.00	270.52	0.000	0.0000	0.
	0.0000	0.	0.00	0.0000	1.1090	500.00	0.00	9.000
	159.00	0.0000	0.0000	0.00	.7790	500.00	0.0000	0.0000
	0.000		0.00	0.	500.00	433.0[illegible]	0.000	
	0.00		0.00	0.	1.5581	20.00	.8000	159.00
	0.0000		0.00	0.0000	0.0000	800.00	5.000	159.28
	5.0000		0.00	0.0000	.6250	200.00	2.7500	.1400
	0.0000		0.00		1.0000	800.00	4.6125	0.00
			0.000		0.0000	.2240	17.143	0.0000
						32.00	[illegible]	
						24.00	300.00	

]

1.00	.0548	0.00	1.0941	353.63	72.000	95.61	2.0359	0.0000
	.4238	.0333	1.0963	0.0000	300.00	.8841	13.903	0.
	44.20	10.000	.1086	0.00	274.19	70.726	0.0000	0.
	.5411	0.	883.41	0.0000	1.1014	500.00	0.00	9.000
	157.90	0.0000	.8841	.18	.7756	500.00	0.0000	0.0000
	17.681		56.46	0.	500.00	489.63	0.000	
	161.74		353.36	0.	1.5513	24.67	.6996	158.97
	.0578		353.63	0.0000	1.4145	777.79	5.000	158.25
	4.7805		238.60	0.0000	1.0000	194.55	2.7500	.1727
	0.0000		.09		1.6000	799.91	4.8125	100.41
			2.258		.8841	.2763	17.143	1.0639
						39.49	0.	
						29.62	300.00	
30.00	.0298	0.00	.5958	189.24	72.000	77.75	3.8989	0.0000
	.2618	.5484	.5953	0.0000	300.00	.4731	9.829	0.
	23.66	13.388	.1163	0.00	503.49	37.849	0.0000	0.
	.9194	0.	473.59	0.0000	.5935	500.00	0.00	12.388
	153.83	0.0000	.4731	114.85	.5784	500.00	0.0000	0.0000
	9.462		453.53	0.	500.00	959.15	0.000	
	121.34		189.44	0.	1.1568	90.49	.6839	155.06
	.9909		189.24	0.0000	.7570	75.44	6.694	155.10
	3.8877		168.51	0.0000	.9199	18.38	2.7500	.6334
	0.0000		167.20		1.4718	804.11	4.8125	116.13
			18.141		.4731	1.0186	17.143	1.2346
						141.80	0.	
						106.35	300.00	
35.00	.0294	0.00	.5881	188.62	72.000	77.13	3.8504	0.0000
	.2620	.5701	.5883	0.0000	300.00	.4715	9.198	0.
	23.58	13.964	.1186	0.00	510.10	37.724	0.0000	0.
	.9525	0.	471.40	0.0000	.5888	500.00	0.00	12.964
	153.20	0.0000	.4715	117.28	.5772	500.00	0.0000	0.0000
	9.431		478.59	0.	500.00	953.57	0.000	
	123.16		188.56	0.	1.1544	88.25	.6814	154.47
	1.0202		188.62	0.0000	.7545	71.46	6.982	154.43
	3.8566		170.32	0.0000	.9181	17.76	2.7500	.6177
	0.0000		168.26		1.4690	800.93	4.8125	118.60
			19.144		.4715	.9895	17.143	1.2675
						140.54	0.	
						105.41	300.00	

40.00	.0305	0.00	.6105	193.64	72.000	76.99	3.7806	0.0000
	.2687	.5714	.6098	0.0000	300.00	.4841	8.592	0.
	24.21	14.556	.1202	0.00	491.37	38.728	0.0000	0.
	.9578	0.	484.65	0.0000	.6077	500.00	0.00	13.556
	152.59	0.0000	.4841	118.47	.5827	500.00	0.0000	0.0000
	9.682		476.82	0.	500.00	941.41	0.000	
	125.08		193.86	0.	1.1654	85.08	.6799	153.87
	1.0254		193.64	0.0000	.7746	69.18	7.278	153.78
	3.8495		173.31	0.0000	.9322	17.14	2.7500	.5955
	0.0000		170.36		1.4915	801.42	4.8125	120.12
			19.073		.4841	.9545	17.143	1.2811
						135.16	0.	
						101.37	300.00	
54.00	.0851	0.00	1.7552	0.00	72.000	76.65	3.9802	0.0000
	.9944	.8292	1.7022	0.0000	657.06	0.0000	5.916	0.
	209.05	16.324	.5721	0.00	374.34	.006	0.0000	0.
	.6423	0.	.04	0.0000	1.5207	500.00	0.00	15.324
	149.92	0.0000	0.0000	142.35	.9462	500.00	0.0000	0.0000
	.001		495.59	0.	880.00	710.10	0.000	
	37.74		.02	0.	1.8924	94.30	.2678	151.85
	1.2136		.03	0.0000	0.0000	71.81	8.162	151.24
	3.8323		51.03	0.0000	.6250	18.75	2.7500	.6601
	0.0000		200.30		0.0000	792.91	4.8125	532.23
			19.824		0.0000	1.0468	51.429	1.9308
						156.22	0.	
						117.17	900.00	
55.00	.4183	0.00	2.2060	0.00	72.000	80.97	4.1439	0.0000
	1.9197	1.4759	2.0000	0.0000	870.84	0.0000	4.238	0.
	209.05	16.475	1.5064	0.00	394.75	.000	0.0000	0.
	.2641	0.	.00	-.6669	2.1892	500.00	0.00	15.475
	148.24	0.0000	0.0000	168.45	1.0000	500.00	0.0000	0.0000
	.000		253.59	0.	880.00	739.70	0.000	
	10.61		.00	0.	2.0000	102.21	-.6669	151.05
	1.0245		.00	0.0000	0.0000	71.56	8.238	149.67
	4.0485		.26	0.0000	.6250	22.38	2.7500	.7155
	0.0000		200.24		0.0000	761.79	4.8125	841.48
			10.144		0.0000	1.0901	51.429	2.8112
						194.78	0.	
						146.09	900.00	

56.00	1.5416	857.95	2.1476	0.00	72.000	85.02	4.3206	.1776
	2.1635	2.0963	2.0000	2.0492	897.67	0.0000	2.426	0.
	209.05	15.693	1.9237	-968.46	417.98	.000	1.8947	0.
	.0927	0.	.00	-1.1153	2.1705	500.00	102.46	14.693
	146.43	.7776	0.0000	247.74	1.0000	500.00	0.0000	2.1449
	.000		99.82	0.	880.00	775.51	0.000	
	3.71		.00	0.	2.0000	111.12	-1.1153	151.21
	.8290		.00	2.1449	0.0000	70.10	7.847	149.77
	4.2509		.00	.9820	.6250	26.32	2.7500	.7778
	1.7922		188.19		0.0000	727.00	4.8125	809.22
			3.993		0.0000	1.1309	51.429	4.0068
						242.68	0.	
						182.01	900.00	
57.00	2.7624	916.26	1.9655	100.00	72.000	88.63	4.4769	1.1800
	2.1963	2.6010	1.9973	1.9332	899.85	.2500	2.104	0.
	209.05	13.891	1.9918	-610.17	457.82	.000	2.3727	0.
	.0294	0.	.00	-1.1908	1.9867	500.00	96.66	12.371
	146.10	1.2066	.2500	358.14	.9987	500.00	.7624	2.2907
	.000		33.94	0.	880.00	835.04	15.248	
	1.18		.00	0.	1.9973	119.30	-1.1908	152.51
	.6508		.00	2.2907	1.0000	67.94	6.945	150.05
	4.4317		.00	2.0805	.6250	30.14	2.7500	.8351
	2.2760		165.93		.2500	692.70	4.8125	801.14
			1.358		.2500	1.1570	51.429	5.1972
						293.29	0.	
						219.97	900.00	
58.00	3.8251	865.94	1.8167	100.94	72.000	89.70	4.6096	1.8466
	1.9718	2.9797	1.9737	1.7780	858.71	.2524	2.331	0.
	244.43	12.219	1.7851	-419.87	472.68	31.756	2.2754	0.
	.2474	0.	396.70	-.9998	1.8686	500.00	88.70	[illegible]
	146.33	1.1813	.2524	469.04	.9869	500.00	1.8251	2.1649
	7.939		57.14	0.	644.44	845.82	36.503	
	72.26		158.68	0.	1.9737	126.48	-.9998	153.30
	.5324		158.78	2.1649	.1588	65.28	6.109	150.29
	4.4852		126.68	2.0874	.6309	33.24	2.7500	[illegible]
	2.1895		138.85		.2524	658.94	4.8125	784.34
			.421		.2524	1.1668	40.000	[illegible]
						345.09	0.	
						258.82	700.00	

59.00	4.4169	703.33	1.4477	100.89	72.000	90.22	4.7182	1.7842
	1.8453	3.2550	1.8962	1.3215	695.85	.2522	2.801	0.
	385.02	10.859	1.6083	-226.51	480.67	31.125	1.9167	0.
	.3978	0.	388.45	-.8129	1.5270	500.00	66.08	9.859
	146.80	1.0391	.2522	562.90	.9481	500.00	2.4169	1.7083
	7.781		150.44	0.	515.56	846.99	48.337	
	78.40		155.38	0.	1.8962	132.51	-.8129	154.89
	.5566		155.62	1.7583	.1556	63.24	5.430	150.51
	4.5112		157.03	1.8914	.6306	37.55	2.7500	.9276
	1.8507		114.80		.2522	627.42	4.8125	795.09
			.123		.2522	1.1639	28.571	7.0450
						394.77	0.	
						296.22	500.00	
60.00	4.6946	486.19	1.0998	100.57	72.000	90.36	4.7879	1.7834
	1.6719	3.4509	1.5970	.9021	530.65	.2514	3.408	0.
	500.59	10.037	1.5026	77.99	482.51	27.129	1.3798	0.
	.4666	0.	335.88	-.7106	1.1522	500.00	45.11	9.037
	147.41	.7703	.2514	635.21	.7985	500.00	2.6946	1.2155
	6.782		211.85	0.	510.00	869.76	53.393	
	72.03		134.35	0.	1.5970	126.45	-.7106	155.51
	.6034		135.65	1.2155	.1356	61.55	5.019	150.65
	4.5181		147.74	1.4432	.6286	41.30	2.7500	.9552
	1.3347		101.54		.2514	598.42	4.8125	792.41
			.034		.2514	1.1432	25.714	7.3337
						438.37	0.	
						328.78	450.00	
61.00	4.8280	349.30	.9517	329.60	72.000	90.34	4.8310	1.3917
	1.4537	3.5710	1.4380	.7193	453.09	.3240	3.338	0.
	561.77	9.715	1.3099	268.70	476.11	23.556	.9932	0.
	.4911	0.	293.26	-.5192	.9726	500.00	35.97	8.715
	147.84	.5419	.8240	704.70	.7193	500.00	2.8280	.8732
	5.889		238.14	0.	504.44	882.86	56.560	
	61.19		117.31	0.	1.4380	120.72	-.5192	155.71
	.6406		117.79	.8732	.3523	60.13	4.857	150.74
	4.5171		125.10	1.0077	.6867	45.04	2.6860	.9724
	.9572		98.42		.3240	571.75	4.7005	790.54
			.009		.3240	1.1120	22.857	7.3346
						475.74	0.	
						356.95	400.00	

62.00	4.6930	272.16	.8574	[illegible]	72.000	83.61	4.8626	1.0314
	1.0251	3.6244	1.3607	.4925	400.23	1.1997	4.092	0.
	162.32	9.674	.3761	551.45	466.51	66.489	.7702	0.
	1.3038	0.	828.50	-.1008	.8759	500.00	24.63	3.674
	148.09	.4246	1.1997	[illegible]	.6804	500.00	2.6930	.6804
	16.622		388.57	0.	500.00	826.17	53.861	
	156.07		331.36	0.	1.3607	140.74	-.1008	155.70
	.7049		332.44	.6804	.9973	58.96	4.837	150.81
	4.1603		294.05	.7770	.9997	48.72	2.6769	.9852
	.7405		101.01		1.1997	547.54	4.6847	774.32
			.042		1.1997	1.0789	20.000	7.1842
						509.45	0.	
						382.06	350.00	
63.00	4.1085	115.33	.7880	[illegible]	72.000	78.25	4.8848	.7686
	.8310	3.6601	1.2903	.0498	350.01	.7876	4.511	0.
	39.38	9.924	.5944	95.32	455.78	63.006	.3741	0.
	1.6732	0.	[illegible]	.1910	.7862	500.00	2.48	8.924
	148.01	.2522	.7876	[illegible]	.6452	500.00	2.1085	.2883
	15.762		[illegible]	0.	500.00	814.46	42.170	
	160.34		314.10	0.	1.2903	142.03	.1990	155.42
	.9274		310.03	.2883	.9451	59.25	4.962	150.87
	3.9123		323.39	.5172	.9945	52.42	2.7330	.9942
	.3716		109.86		1.1934	530.60	4.7827	792.87
			.001		.7876	1.0551	17.143	6.6529
						533.37	0.	
						400.02	300.00	
64.00	3.3298	9.72	.6712	299.16	72.000	74.46	4.8973	.4538
	.7703	3.7058	1.2239	0.0000	300.00	.7479	4.914	0.
	37.40	10.354	.3244	-.99	446.93	59.833	0.0000	0.
	1.6402	0.	[illegible]	.2737	.6913	500.00	0.00	9.554
	148.91	.0486	.7479	755.87	.6119	500.00	1.3298	.0243
	14.986		334.72	0.	500.00	[illegible]	26.596	
	152.28		[illegible]	0.	1.2239	142.79	.2737	154.71
	[illegible]		[illegible]	.0243	.3973	[illegible]	5.277	150.97
	[illegible]		[illegible]	.1276	.7890	[illegible]	2.7500	.9995
	[illegible]		[illegible]		1.1888	[illegible]	4.8125	[illegible]
			.000		.7479	1.0408	14.286	5.7777
						547.59	0.	
						[illegible]	250.00	

65.00	2.[illegible]	.57	.5683	282.67	72.000	71.48	4.9012	.1725
	.7272	3.7430	1.1602	0.0000	250.32	.7067	5.165	0.
	33.33	11.300	.4926	-.00	442.46	56.533	0.0000	0.
	1.5437	0.	704.87	.3060	.6003	500.00	0.00	10.305
	119.17	.0039	.7067	765.05	.5801	500.00	.4757	.0017
	14.133		805.03	0.	500.00	799.38	9.513	
	144.03		281.95	0.	1.1602	142.99	.3060	153.95
	1.2022		282.67	.0017	1.1307	62.98	5.653	151.17
	3.3738		290.84	.0114	1.0000	59.95	2.7500	1.0009
	.0046		156.22		1.6000	512.32	4.8125	798.56
			.000		.7067	1.0256	14.286	4.7818
						557.87	0.	
						418.40	250.00	
68.00	.5579	.00	.5496	363.70	72.000	62.62	4.8879	.0021
	.5057	2.6211	1.1355	0.0000	250.00	.9092	5.915	0.
	45.46	13.568	.2299	-.00	454.90	72.739	0.0000	0.
	1.7868	0.	909.11	0.0000	.5509	500.00	0.00	12.568
	149.91	.0000	.9092	692.14	.5677	500.00	0.0000	.0000
	18.185		874.55	0.	500.00	801.20	0.000	
	230.76		363.64	0.	1.1355	142.21	.5698	152.81
	1.6383		363.70	.0000	1.4548	68.69	6.784	151.91
	3.1309		327.77	.0000	1.0000	64.64	2.7500	.9955
	.0000		232.66		1.6000	515.18	4.8125	230.16
			30.092		.9092	1.0257	14.286	2.8959
						551.58	0.	
						413.68	250.00	
70.00	.0268	.00	.5360	172.24	72.000	62.44	4.8683	.0001
	.2665	1.8358	.5362	0.0000	250.00	.4306	6.609	0.
	21.53	14.782	.1567	-.00	466.45	34.448	0.0000	0.
	1.4589	0.	430.35	0.0000	.5371	500.00	0.00	13.782
	150.61	.0000	.4306	514.72	.5643	500.00	0.0000	.0000
	8.612		854.99	0.	500.00	813.35	0.000	
	140.91		172.14	0.	1.1286	141.08	.6393	152.38
	1.7371		172.24	.0000	.6890	73.06	7.391	152.58
	3.1220		178.70	.0000	.9745	65.63	2.7500	.9875
	.0000		270.64		1.3992	526.77	4.8125	160.66
			33.689		.4306	1.0404	14.286	1.7737
						534.10	0.	
						400.5[illegible]	250.00	

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Captain Gordon LeMaire graduated from the University of Southwestern Louisiana with a Bachelor of Science degree in Secondary Education. He received his commission through ROTC in May 1974 and reported to Vance AFB for pilot training. After completion of pilot training he was assigned to the 463rd Tactical Airlift Wing. He served there until being chosen to attend AFIT. His next assignment will be at Headquarters Military Airlift Command, Scott AFB, Illinois.

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